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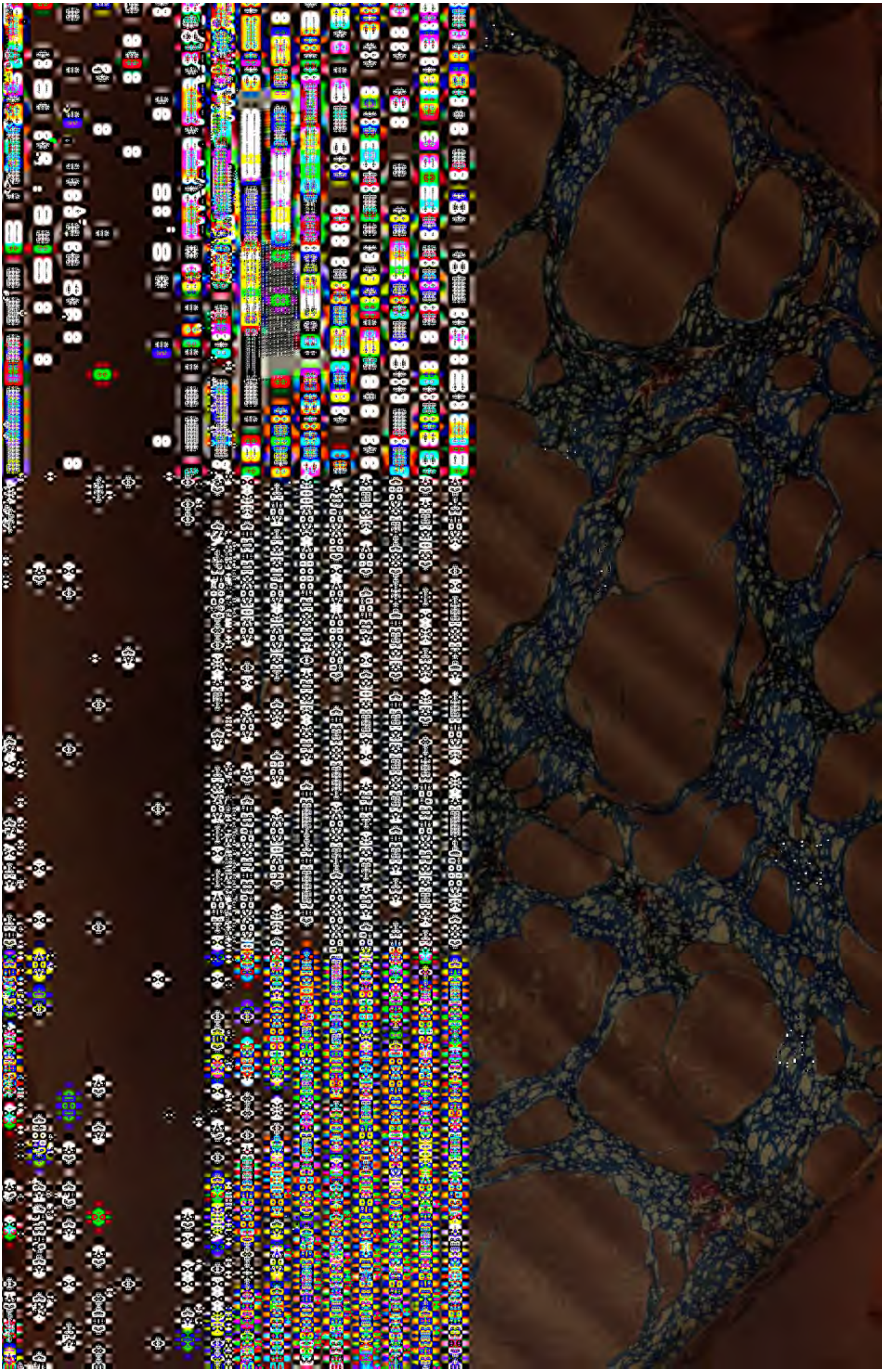

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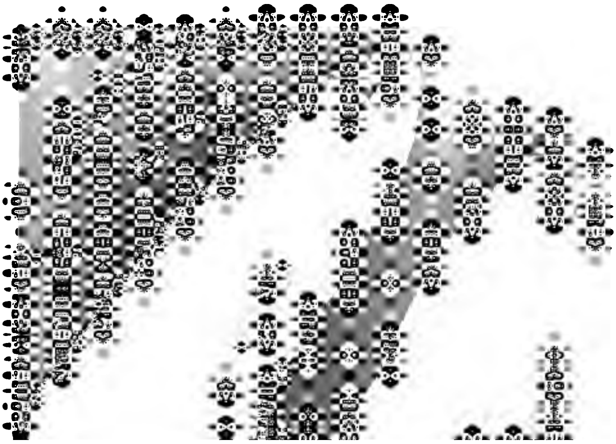

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TRANSACTIONS

OF

THE INSTITUTION

OF

MINING ENGINEERS.

VOL. XVII.—1898-99.

EDITED BY M. WALTON BROWN, SECRETARY.

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The Institution, as a body, is not responsible for the statements facts and opinions advanced in any of its publications.

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ANY PUBLICATION OF A FEDERATED INSTITUTE MAY BE PLACED AT THE END OF THE VOLUME, *i e.*, "ANNUAL REPORT," "LIST OF MEMBERS," ETC., ETC.

THE INSTITUTION OF MINING ENGINEERS.

FOUNDED JULY 1ST, 1889.

BYE-LAWS

As revised at Council Meeting held on July 13th, 1898.

I.—CONSTITUTION.

1.—The Institution of Mining Engineers shall consist of all or any of the societies interested in the advancement of mining, metallurgy, engineering and their allied industries, who shall from time to time join together and adhere to the Bye-Laws.

2.—The Institution shall have for its objects—

(*a*) The advancement and encouragement of the sciences of mining, metallurgy engineering, and their allied industries.

(*b*) The interchange of opinions, by the reading of communications from members and others, and by discussions at general meetings, upon improvements in mining, metallurgy, engineering, and their allied industries.

(*c*) The publication of original communications, discussions, and other papers connected with the objects of the Institution.

(*d*) The purchase and disposal of real and personal property for such objects.

(*e*) The performance of all things connected with or leading to the purpose of such objects.

3.—The offices of the Institution shall be in Newcastle-upon-Tyne, or such other place as shall be from time to time determined by resolution of the Council.

4.—The year of the Institution shall end on July 31st in every year.

5.—The affairs and business of the Institution shall be managed and controlled by the Council.

II.—MEMBERSHIP.

6.—The original adherents or founders are as follows:—

(*a*) Chesterfield and Midland Counties Institution of Engineers, Chesterfield.

(*b*) Midland Institute of Mining, Civil and Mechanical Engineers, Barnsley.

(*c*) North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne.

(*d*) South Staffordshire and East Worcestershire Institute of Mining Engineers, Birmingham.

7.—Written applications from societies to enter the Institution shall be made to the Council, by the President of the applying society, who shall furnish any information that may be desired by the Council.

8.—A.—If desired by the Council, any of the Federated Institutes shall revise their Bye-Laws, in order that their members shall consist of Ordinary Members. Associate Members, and Honorary Members, with Associates and Students, and section B following shall be a model Bye-Law to be adopted by any society when so desired by the Council.

B.—"The members shall consist of Ordinary Members, Associate Members and Honorary Members, with Associates and Students:—

(*a*) Each Ordinary Member shall be more than twenty-three years of age, have been regularly educated as a mining, metallurgical, or mechanical engineer, or in some other branch of engineering, according to the usual routine of pupilage, and have had subsequent employment for at least two years in some responsible situation as an engineer; or if he has not undergone the usual routine of pupilage, he must have been employed or have practised as an engineer for at least five years.

(*b*) Each Associate Member shall be a person connected with or interested in mining, metallurgy, or engineering, and not practising as a mining, metallurgical, or mechanical engineer, or some other branch of engineering.

(*c*) Each Honorary Member shall be a person who has distinguished himself by his literary or scientific attainments, or who may have made important communications to any of the Federated Institutes.

(*d*) Associates shall be persons acting as under-viewers, under-managers, or in other subordinate positions in mines or metallurgical works, or employed in analogous positions in other branches of engineering.

(*e*) Students shall be persons who are qualifying themselves for the profession of mining, metallurgical, or mechanical engineering, or other branch of engineering, and such persons may continue Students until they attain the age of twenty-five years."

9.—The Ordinary Members, Associate Members and Honorary Members, Associates and Students shall have notice of, and the privilege of attending, the ordinary and annual general meetings, and shall receive all publications of the Institution. They may also have access to, and take part in, the general meetings of any of the Federated Institutes.

10.—The members of any Federated Institute, whose payments to the Institution are in arrear, shall not receive the publications and other privileges of the Institution.

11.—After explanations have been asked by the President from any Federated Institute, whose payments are in arrear, and have not been paid within one month after written application by the Secretary, the Council may decide upon its suspension or expulsion from the Institution; but such suspension or expulsion shall only be decided at a meeting attended by at least two-thirds of the members of the Council by a majority of three-fourths of the members present.

III.—SUBSCRIPTIONS.

12.—Each of the Federated Institutes shall pay fifteen shillings per annum for each Ordinary Member, Associate Member, Honorary Member, Associate and Student, or such other sum, and in such instalment or instalments as may be determined from time to time by resolution or resolutions of the Council. Persons joining any of the Federated Institutes during the financial year of the Institution shall be entitled to all publications issued for that year, after his election is notified to the Secretary, and the instalment or instalments due on his behalf have been paid.

IV.—ELECTION OF OFFICERS AND COUNCIL.

13.—The officers of the Institution, other than the Secretary and Treasurer, shall consist of Councillors elected annually prior to August in each year, by and out of the Ordinary Members and Associate Members of each Federated Institute, in the proportion of one Councillor per forty Ordinary Members or Associate Members thereof; of Vice-Presidents elected by and from the Council at their first meeting in each year on behalf of each Institute, in the proportion of one Vice-President per two hundred Ordinary Members or Associate Members thereof; and of a President elected by and from the Council at their first meeting in each year; who, with the Local Secretaries of each Federated Institute and the Secretary and Treasurer, shall form the Council. All Presidents on retiring from that office shall be *ex-officio* Vice-Presidents so long as they continue Ordinary Members or Associate Members of any of the Federated Institutes.

14.—In case of the decease, expulsion, or resignation of any officer or officers, the Council may, if they deem it requisite, fill up the vacant office or offices at their next meeting.

V.—DUTIES OF OFFICERS AND COUNCIL.

15.—The Council shall represent the Institution and shall act in its name, and shall make such calls upon the Federated Institutes as they may deem necessary, and shall transact all business and examine accounts, authorise payments and may invest or use the funds in such manner as they may from time to time think fit, in accordance with the objects and Bye-Laws of the Institution.

16.—The Council shall decide the question of the admission of any society, and may decree the suspension or expulsion of any Federated Institute for non-payment of subscriptions.

17.—The Council shall decide upon the publication of any communications.

18.—There shall be three ordinary meetings of the Council in each year, on the same day as, but prior to, the ordinary or annual general meetings of the members.

19.—A special meeting of the Council shall be called whenever the President may think fit, or upon a requisition to the Secretary signed by ten or more of its members, or by the President of any of the Federated Institutes. The business transacted at a special meeting of the Council shall be confined to that specified in the notice convening it.

20.—The meetings of the Council shall be called by circular letter, issued to all the members at least seven days previously, accompanied by an agenda-paper, stating the nature of the business to be transacted.

21.—The order in which business shall be taken at the ordinary and annual general meetings may be, from time to time, decided by the Council.

22.—The Council may communicate with the Government in cases of contemplated or existing legislation, of a character affecting the interests of mining. metallurgy, engineering, or their allied industries.

23.—The Council may appoint Committees, consisting of members of the Institution, for the purpose of transacting any particular business, or of investigating any specific subject connected with the objects of the Institution.

24.—A Committee shall not have power or control over the funds of the Institution, beyond the amount voted for its use by the Council.

25.—Committees shall report to the Council, who shall act thereon and make use thereof as they may elect.

26.—The President shall take the chair at all meetings of the Institution, the Council, and Committees at which he may be present.

27.—In the absence of the President, it shall be the duty of the senior Vice-President present to preside at the meetings of the Institution. In case of the absence of the President and of all the Vice-Presidents, the meeting may elect any member of Council, or in case of their absence any Ordinary Member or Associate Member to take the chair at the meeting.

28.—At meetings of the Council six shall be a quorum.

29.—Every question shall be decided at the meetings of the Council by the votes of the majority of the members present. In case of equal voting, the President, or other member presiding in his absence, shall have a casting vote. Upon the request of two members, the vote upon any question shall be by ballot.

30.—The Secretary shall be appointed by and shall act under the direction and control of the Council. The duties and salary of the Secretary shall be fixed and varied from time to time at the will of the Council.

31.—The Secretary shall summon and attend all meetings of the Council, and the ordinary and annual general meetings of the Institution, and shall record the proceedings in the minute book. He shall direct the administrative and scientific publications of the Institution. He shall have charge of and conduct all correspondence relative to the business and proceedings of the Institution, and of all committees where necessary, and shall prepare and issue all circulars to the members.

32.—One and the same person may hold the office of Secretary and Treasurer.

33.—The Treasurer shall be appointed annually by the Council at their first meeting in each year. The income of the Institution shall be received by him, and shall be paid into Messrs. Lambton & Co.'s bank at Newcastle-upon-Tyne, or such other bank as may be determined from time to time by the Council.

34.—The Treasurer shall make all payments on behalf of the Institution, by cheques signed by two members of Council, the Treasurer and the Secretary after payments have been sanctioned by Council.

35.—The surplus funds may, after resolution of the Council, be invested in Government securities, in railway and other debenture shares such as are allowed for investment by trustees, in the purchase of land, or in the purchase, erection. alteration, or furnishing of buildings for the use of the Institution. All investments shall be made in the names of Trustees appointed by the Council.

36.—The accounts of the Treasurer and the financial statement of the Council shall be audited and examined by a chartered accountant, appointed by the Council at their first meeting in each year. The accountants' charges shall be paid out of the funds of the Institution.

37.—The minutes of the Council's proceedings shall at all times be open to the inspection of the Ordinary Members and Associate Members.

VI.—GENERAL MEETINGS.

38.—An ordinary general meeting shall be held in February, May and September, unless otherwise determined by the Council; and the ordinary general meeting in the month of September shall be the annual general meeting at which a report of the proceedings, and an abstract of the accounts of the previous year ending July 31st, shall be presented by the Council. The ordinary general meeting in the month of May shall be held in London, at which the President may deliver an address.

39.—Invitations may be sent by the Secretary to any person whose presence at discussions shall be thought desirable by the Council, and persons so invited shall be permitted to read papers and take part in the proceedings and discussions.

40.—Discussion may be invited on any paper published by the Institution, at meetings of any of the Federated Institutes, at which the writer of the paper may be invited to attend. Such discussion, however, shall in all cases be submitted to the writer of the paper before publication, and he may append a reply at the end of the discussion.

VII.—PUBLICATIONS.

41.—The publications may comprise:—

(*a*) Papers upon the working of mines, metallurgy, engineering, railways and the various allied industries.

(*b*) Papers on the management of industrial operations.

(*c*) Abstracts of foreign papers upon similar subjects.

(*d*) An abstract of the patents relating to mining and metallurgy, etc.

(*e*) Notes of questions of law concerning mines, manufactures, railways, etc.

42.—Each paper (with complete drawings, if any, to scale), to be read at any meeting of the Institution or of any of the Federated Institutes, shall be placed in the hands of the Secretary at least fourteen days before the date of the meeting at which the paper is to be read, and shall, subject to the approval of the Council, be printed, together with any discussion or remarks thereon.

43.—The Council may accept communications from persons who are not members of the Institution and allow them to be read at the ordinary or annual general meetings.

44.—No paper which has already been published (except as provided for in Bye-Law 41) shall appear in the publications of the Institution.

45.—A paper in course of publication cannot be withdrawn by the writer.

46.—Proofs of all papers and reports of discussions forwarded to any person for revision must be returned to the Secretary within seven days from the date of their receipt, otherwise they will be considered correct and be printed off.

47.—The copyright of all papers accepted for printing by the Council shall become vested in the Institution, and such communications shall not be published for sale or otherwise without the written permission of the Council.

48.—Twenty copies of each paper and the accompanying discussion shall be presented to the writer free of cost. He may also obtain additional copies upon payment of the cost to the Secretary, by an application attached to his paper. These copies must be unaltered copies of the paper as appearing in the publication of the Institution, and the cover shall state that it is an "Excerpt from the Transactions of The Institution of Mining Engineers."

49.—The Federated Institutes may receive copies of their own portion of the publications in respect of such of their members as do not become members of the Institution, and shall pay 10s. per annum in respect of every copy so supplied; and similar copies for exchanges shall be paid for at cost price.

50.—The Local Secretary of each Federated Institute shall prepare and edit all papers and discussions of such Institute, and promptly forward them to the Secretary, who shall submit proofs to the Local Secretary before publication.

51.—A list of the members, with their last known addresses, shall be printed in the publications of the Institution.

52.—The publications of the Institution shall only be supplied to members, and no duplicate copies of any portion of the publications shall be issued to any member or Federated Institute unless by order of the Council.

53.—The annual volume or volumes of the publications may be sold, in the complete form only, at such prices as may be determined from time to time by the Council:—to non-members for not less than £3; and to members who are desirous of completing their sets of the publications, for not less than 15s.

54.—The Institution as a body is not responsible for the statements and opinions advanced in the papers which may be read or in the discussions which may take place at the meetings of the Institution. or of the Federated Institutes.

VIII.—MEDALS AND OTHER REWARDS.

55.—The Council may award annually the sum of twenty pounds, in the form of medals or other rewards, to the authors of papers published by the Institution.

IX.—PROPERTY.

56.—The capital fund shall consist of such amounts as shall from time to time be determined by resolution of the Council.

57.—The Institution may make use of the following receipts for its expenses :—

(*a*) The interest of its accumulated capital fund ;
(*b*) The annual subscriptions ; and
(*c*) Receipts of all other descriptions.

58.—The Institution may form a collection of papers, books and models.

59.—Societies or members who may have ceased their connexion with the Institution shall have no claim to participate in any of its properties.

60.—All donations to the Institution shall be acknowledged in the annual report of the Council.

X.—ALTERATION OF BYE-LAWS.

61.—No alteration shall be made in the Bye-Laws of the Institution, except at a special meeting of the Council called for that purpose, and the particulars of every such alteration shall be announced at their previous meeting and inserted in the minutes, and shall be sent to all members of Council at least fourteen days previous to such special meeting, and such special meeting shall have power to adopt any modification of such proposed alteration of the Bye-Laws, subject to confirmation by the next ensuing Council meeting.

THE INSTITUTION OF MINING ENGINEERS.

OFFICERS, 1898-99.

Past-Presidents (*ex-officio*).

Mr. W. N. Atkinson, H.M. Inspector of Mines, Barlaston, Stoke-upon-Trent.
Mr. George Lewis, Albert Street, Derby.
Mr. George A. Mitchell, 5, West Regent Street, Glasgow.
Mr. Arthur Sopwith, Cannock Chase Collieries, near Walsall.
Sir Lindsay Wood, Bart., The Hermitage, Chester-le-Street.

President.

Mr. J. A. LONGDEN, Stanton-by-Dale, near Nottingham.

Vice-Presidents.

Mr. William Armstrong, Wingate, Co. Durham.
Mr. William Henry Chambers, Conisborough, Rotherham.
Mr. William Cochrane, St. John's Chambers, Grainger Street West, Newcastle-upon-Tyne.
Mr. James T. Forgie, Bothwell Collieries, Bothwell, Glasgow.
Mr. G. B. Forster, 3, Eldon Square, Newcastle-upon-Tyne.
Mr. James Hamilton, 208, St. Vincent Street, Glasgow.
Mr. W. D. Holford, Hill House, Old Whittington, Chesterfield.
Sir William Thomas Lewis, Bart., Mardy, Aberdare.
Mr. George May, The Harton Collieries, South Shields.
Mr. M. H. Mills, Sherwood Hall, Mansfield.
Mr. Joel Settle, The Hill, Alsager, Stoke-upon-Trent.
Mr. J. B. Simpson, Bradley Hall, Wylam-upon-Tyne.
Mr. G. Blake Walker, Wharncliffe Silkstone Colliery, Barnsley.
Mr. James Wallace, Wester Gartshore Colliery, Kirkintilloch, Glasgow.
Mr. R. S. Williamson, Cannock Wood House, Hednesford, Staffordshire.

Council.

* Deceased.

Mr. Henry Armstrong, Chester-le-Street.
Mr. J. B. Atkinson, H.M. Inspector of Mines, 10, Foremount Terrace, Glasgow.
Mr. Henry Ayton, 122, Rye Hill, Newcastle-upon-Tyne.
Mr. R. Donald Bain, H.M. Inspector of Mines, Springwell Hall, Durham.
Mr. James Barrowman, Staneacre, Hamilton, N.B.
Mr. T. W. Benson, 24, Grey Street, Newcastle-upon-Tyne.
Mr. G. J. Binns, Duffield House, Duffield, Derby.
Mr. Bennett H. Brough, Cranleigh House, Woodham, near Addlestone, Surrey.
Mr. M. Walton Brown, 10, Lambton Road, Newcastle-upon-Tyne.
Mr. H. M. Cadell, Grange, Bo'ness, R.S.O., Linlithgowshire.
Mr. G. E. Coke, 65, Station Street, Nottingham.
Mr. Maurice Deacon, Whittington House, near Chesterfield.
Mr. James S. Dixon, Fairleigh, Bothwell, N.B.
Mr. H. St. John Durnford, Ackton Hall Colliery, Featherstone, near Pontefract.
Mr. T. E. Forster, 3, Eldon Square, Newcastle-upon-Tyne.
Mr. W. E. Garforth, West Riding Colliery, Normanton.
Mr. John Gerrard, H.M. Inspector of Mines, Worsley, Manchester.
Mr. Nathaniel R. Griffith, Plasnewydd, Ruabon, North Wales.
Mr. J. Richard Haines, Adderley Green Collieries, Stoke-upon-Trent.
Mr. W. F. Hall Haswell Colliery, Haswell, *via* Sunderland.
Mr. James Hastie, Greenfield Colliery, Hamilton, N.B.

Mr. W. J. Hayward, West Bromwich.
*Mr. Jeremiah Head, 47, Victoria Street, Westminster, London, S.W.
Mr. Archibald Hood, 6, Bute Crescent, Cardiff.
Mr. James A. Hood, Rosewell, Midlothian.
*Mr. W. F. Howard, Ivy Grove, Clarence Road, Chesterfield.
*Mr. John Jackson, Stubben Edge, Chesterfield.
Mr. A. C. Kayll, Gosforth, Newcastle-upon-Tyne.
Mr. Henry Lawrence, 7 and 8, Post Office Chambers, Newcastle-upon-Tyne.
*Mr. Henry Lewis, Annesley Colliery, Nottingham.
Mr. Jonathan Longbotham, Sharrow House, Sheffield.
Mr. Henry Louis, 9, Summerhill Terrace, Newcastle-upon-Tyne.
Mr. Hugh R. Makepeace, H.M. Inspector of Mines, Trentham, Stoke-upon-Trent.
Mr. Henry W. Martin, Trewern, Dowlais, Glamorganshire.
Mr. T. W. H. Mitchell, Mining Offices, Barnsley.
Mr. C. A. Moreing, Broad Street House, Old Broad Street, London, E.C.
Mr. John Morison, Cramlington House, Northumberland.
Mr. H. B. Nash, Clarke's Old Silkstone Colliery, Barnsley.
Mr. John Nevin, Littlemoor House, Mirfield.
Mr. Henry Palmer, Medomsley, R.S.O., Co. Durham.
Mr. H. C. Peake, Walsall Wood Colliery, Walsall.
Mr. John Ridyard, Hilton Bank, Little Hulton, Bolton-le-Moors, Lancashire.
Mr. J. M. Ronaldson, H.M. Inspector of Mines, 44, Athole Gardens, Glasgow.
Mr. Fred. J. Rowan, 121, West Regent Street, Glasgow.
Mr. A. R. Sawyer, c/o Messrs. Fletcher's Wholesale, Cape Town, South Africa; and Hilhouse, Woking, Surrey.
Mr. F. R. Simpson, Hedgefield House, Blaydon-upon-Tyne.
Mr. Alexander Smith, 3, Newhall Street, Birmingham.
Mr. A. L. Steavenson, Durham.
Mr. John Strick, Bar Hill, Madeley, Staffordshire.
Mr. E. W. Thirkell, Oaks Colliery, Barnsley.
Mr. Wallace Thorneycroft, Rockdale Lodge, Stirling, N.B.
Mr. E. B. Wain, Whitfield Collieries, Norton-in-the-Moors, Stoke-upon-Trent.
Mr. Frank N. Wardell, H.M. Inspector of Mines, Wath-upon-Dearne, near Rotherham.

Auditors.

Messrs. John G. Benson & Son, Newcastle-upon-Tyne.

Treasurers.

Messrs. Lambton & Company, The Bank, Newcastle-upon-Tyne.

Secretary.

Mr. M. Walton Brown, Neville Hall, Newcastle-upon-Tyne.

LIST OF MEMBERS.

Honorary Members.

* Deceased.

The Institution of Mining Engineers.

Hon.M.Inst.M.E.

J. B. Atkinson, H.M. Inspector of Mines, 10, Foremount Terrace, Glasgow.
W. N. Atkinson, H.M. Inspector of Mines, Barlaston, Stoke-upon-Trent.
R. Donald Bain, H.M. Inspector of Mines, Springwell Hall, Durham.
W. Beattie-Scott, H.M. Inspector of Mines, Park Avenue, Handsworth, near Birmingham.

C. Le Neve Foster, H.M. Inspector of Mines, Llandudno.
Sir Archibald Geikie, Director-General of the Geological Survey of the United Kingdom, 28, Jermyn Street, London, S.W.
John Gerrard, H.M. Inspector of Mines, Worsley, Manchester.
G. C. Greenwell, Duffield, Derby.
Henry Hall, H.M. Inspector of Mines, Rainhill, Lancashire.
J. L. Hedley, H.M. Inspector of Mines, 2, Devonshire Terrace, Newcastle-upon-Tyne.
J. S. Martin, H.M. Inspector of Mines, The Vikings, 16, Durdham Park, Bristol.
Joseph T. Robson, H.M. Inspector of Mines, Ravensworth, Eaton Grove Swansea.
J. M. Ronaldson, H.M. Inspector of Mines, 44, Athole Gardens, Glasgow.
A. H. Stokes, H.M. Inspector of Mines, Greenhill, Derby.
Frank N. Wardell, H.M. Inspector of Mines, Wath-upon-Dearne, near Rotherham.

Chesterfield and Midland Counties Institution of Engineers.

Prof. Frank Clowes, 18, Bedford Court Mansions, Bedford Square, London, W.C.
Rev. J. M. Mello, Mapperley Vicarage, near Derby.

Midland Institute of Mining, Civil and Mechanical Engineers.

Prof. G. F. Armstrong, The University, Edinburgh.
Joseph Dickinson, South Bank, Sandy Lane, Pendleton, Manchester.
Prof. J. Goodman, Yorkshire College, Leeds.
Prof. L. C. Miall, Yorkshire College, Leeds.
Prof. A. W. Rucker, 19, Gledhow Gardens, South Kensington, London, S.W.
Prof. R. Russell, 1, Sea View, St. Bees, Carnforth.
Prof. T. E. Thorpe, The Government Laboratory, Somerset House, London, W.C.

The North of England Institute of Mining and Mechanical Engineers.

Prof. P. Phillips Bedson, Durham College of Science, Newcastle-upon-Tyne.
Thomas Bell, 15, The Valley, Scarborough.
Prof. G. S. Brady, Durham College of Science, Newcastle-upon-Tyne. *Transactions* to be sent to Mowbray Villa, Sunderland.
Dr. Brassert, Bonn-on-the-Rhine, Germany.
Joseph Dickinson, South Bank, Sandy Lane, Pendleton, Manchester.
Prof. William Garnett, 116, St. Martin's Lane, London, W.C.
Rev. H. Palin Gurney, Principal of the Durham College of Science, Roseworth, Gosforth, Newcastle-upon-Tyne.
*William Henry Hedley, 34, Beverley Terrace, Cullercoats.
Prof. A. S. Herschel, Observatory House, Slough, Bucks.
Prof. G. A. Lebour, Durham College of Science, Newcastle-upon-Tyne. *Transactions* to be sent to Radcliffe House, Corbridge-upon-Tyne.
Prof. Henry Louis, 9, Summerhill Terrace, Newcastle-upon-Tyne. *Transactions* to be sent to the Secretary, Durham College of Science, Newcastle-upon-Tyne.
Sir Charles Mark Palmer, Bart., Grinkle Park, Loftus, R.S.O., Yorkshire. *Transactions* to be sent to the Mechanics' Institute, Jarrow-upon-Tyne.
Prof. H. Stroud, Durham College of Science, Newcastle-upon-Tyne.
Prof. Robert Lunan Weighton, Durham College of Science, Newcastle-upon-Tyne. *Transactions* to be sent to 21, North Terrace, Newcastle-upon-Tyne.

North Staffordshire Institute of Mining and Mechanical Engineers.

W. N. Atkinson, H.M. Inspector of Mines, Barlaston, Stoke-upon-Trent.
Hugh R. Makepeace, H.M. Inspector of Mines, Trentham, Stoke-upon-Trent.
Henry Skiffington Poole, Acadia Coal Company, Limited, Stellarton, Nova Scotia.

A. R. **Sawyer**, c/o Messrs. Fletcher's Wholesale, Cape Town, South Africa; and Hilhouse, Woking, Surrey.
C. M. **Stuart**, St. Dunstan's College, Lewisham.

South Staffordshire and East Worcestershire Institute of Mining Engineers.

Prof. C. **Lapworth**, Mason College, Birmingham.
Prof. R. H. **Smith**, Ellerslie, Sutton, Surrey.

Members.

M.Inst.M.E.

* Deceased.

Abraham, David, Pencoedcae, Merthyr Tydvil.
Aburrow, Charles, P.O. Box 534, Johannesburg, Transvaal.
Ackroyd, A., Morley Main Collieries, Leeds.
Adams, David, Muircambus, Colinsburgh, R.S.O., Fifeshire.
Adams, Henry Hopper, Waihi, New Zealand.
Adamson, James C., Victoria Place, Airdrie, N.B.
Adamson, Robert, P.O. Box 309, Bulawayo, Rhodesia, South Africa.
Adamson, T., St. John's Road, Southall, Middlesex.
Addie, Robert, c/o The Smelting Corporation, Limited, Ellesmere Port, Cheshire.
Agassiz, Alexander, Museum of Comparative Zoology, Cambridge, Massachusetts, U.S.A.
Ainsworth, J. W., Bridgewater Trustees Collieries, Walkden, near Bolton, Lancashire.
Aitken, Henry, Darroch, near Falkirk, N.B.
Alexander, William Edward Cayley, Thermo-Hyperphoric Ore Treating Syndicate, Limited, 168 and 169, Dashwood House, New Broad Street, London, E.C.
Alison, Robert, Greymouth Point Elizabeth Railway and Coal Company, Limited, Brunnerton, New Zealand.
Allan, Alexander B., 7, Campside Crescent, Langside, Glasgow.
Allan, James, Hillhead, Coylton, Ayr, N.B.
Allan, John F., Apartado de Correo, No. 121, Mexico, D.F.
Allan, T. A., c/o Gibbs, Bright and Company, Melbourne, Australia.
Allchurch, Enrique, Calle Las Heras, 273, Buenos Aires, Argentine Republic.
Allen, Reuben, Birch Coppice Colliery, Polesworth, near Tamworth.
Allison, John, 116, Woodlands Road, Glasgow.
Allison, J. J. C., Woodland Collieries, Butterknowle, R.S.O., Co. Durham.
Allsop, Samuel, Marehay Collieries, Derby.
Alsop, A. B., Rosekenwyn, Pinxton, Alfreton.
Alsop, A. M., Lead Mines, Darley Dale, Matlock.
Alsop, Samuel. Codnor, Derby.
Alston, Charles F., P.O. Box 111, Greenwood, British Columbia.
Altenhein, C. R., c/o W. E. Koch and Compeny, Foster's Buildings, High Street, Sheffield.
Anderson, C. W., Cleadon Park, Sunderland.
Anderson, George, Martin Place, Sydney, Australia.
Anderson, James, Farme Colliery, Rutherglen, Glasgow.
Anderson, John, Ashton House, Plains, Airdrie, N.B.
Anderson, J. **Everard**, The Transvaal Gold Mining Estates, Limited Pilgrim's Rest, South African Republic.
Anderson, R. **Hay**, Apartado Postal, 866, Mexico, D.F.
Anderson, R. S., Benwell View, Bentinck Road, Newcastle-upon-Tyne.
Anderson, Walter G., c/o F. C. Anderson, Union Cottage, Dumbarton.
Andrew, Robert, c/o John Munro, 30, George Square, Glasgow.
Andrews, Thomas, Wortley Iron Works, near Sheffield.
Angus, James, Ochiltree House, Ochiltree, Ayrshire, N.B.
Angwin, B., c/o Holman Brothers, Broad Street House, London, E.C.

Anley, James P. B., The Avenue, Kidsgrove, Stoke-upon-Trent.
Appleby, Harry Walton, Trafalgar Works, Bradford, Yorkshire.
Appleby, W. R., 91 Fifth Street, S.E., Minneapolis, Minnesota, U.S.A.
Archer, Joseph, Royal Insurance Buildings, Church Street, Sheffield.
Archer, Oakeley, 156 Hereford Street, Christchurch, New Zealand.
Archer, T., 11, Regent Terrace, Gateshead-upon-Tyne.
Archer, William, Victoria Garesfield, Lintz Green.
Archibald, David, Lassodie Colliery, by Dunfermline, N.B.
Argall, Captain J.
Argall, Philip, P.O. Box 843, Denver, Colorado, U.S.A.
Armour, James, Clippens Oil Works, Loanhead, N.B.
Armson, Jesse, Donisthorpe Colliery, Ashby-de-la-Zouch.
Armstrong, Henry, Chester-le-Street.
Armstrong, Lord, C.B., LL.D., D.C.L., Cragside, Rothbury.
Armstrong, William, Wingate, Co. Durham.
Arnott, Thomas, Fernbank, Newton, Glasgow.
Ashcroft, Edgar Arthur, 13, Victoria Street, Westminster, London, S.W.
Ashmore, G. Percy, c/o G. Harris Ganteaume, Agent, Caratal (New) Mines, Limited, Cuidad Bolivar, Venezuela, South America, via Trinidad.
Ashton, J. H., Waleswood Colliery, near Rotherham.
Ashwin, G. H., Marlpool House, Derby.
Ashworth, John, 8, King Street, Manchester.
Ashworth, Thomas, 25, Regent Road, Fenton, Stoke-upon-Trent.
Askew, George H., Brayton Domain Collieries, Aspatria, Cumberland.
*Asquith, T. W., Harperley Hall, Tantobie, R.S.O., Co. Durham.
Aston, J., Blowers Green, Dudley, Worcestershire.
Atherton, James, 13, Mawdsley Street, Bolton, Lancashire.
Atherton, Samuel, Hanwood and Shorthill Collieries, near Shrewsbury.
Atherton, Thomas William Turner, Mijnbouw Maatschappij, Bwool, North Celebes.
Atkins, S. S., Sempore Colliery, Asansol, India.
Atkinson, A. A., Chief Inspector of Coal Mines, c/o Hon. Minister of Mines and Agriculture, Sydney, New South Wales.
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Atkinson, Fred. R., West Street, Congleton.
Atkinson, J. B., H.M. Inspector of Mines, 10, Foremount Terrace, Glasgow.
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Atkinson, L. B., 10, Westbourne Road, Penarth, South Wales.
Atkinson, R. Hugh M. Buddle, Riding Mill-upon-Tyne.
Atkinson, T. D., Hearn House, Chesterfield.
Atkinson, W. N., H.M. Inspector of Mines, Barlaston, Stoke-upon-Trent.
Aubrey, R. C., Teviotdale, Churchtown, Southport.
Austin, Tom Wilson, Baddesley Colliery, Atherstone, Warwickshire.
Austin, W. Lawrence, P.O. Box 941, Denver, Colorado, U.S.A.
Ayton, Ernest F., El Bote Mining Negociacion, Zacatecas, Republic of Mexico.
Ayton, Henry, 122, Rye Hill, Newcastle-upon-Tyne.

Bagshaw, James, Brampton Iron Works, Chesterfield.
Bailes, E. T., Wingate, Ferryhill.
Bailes, G. M., Hinckley Road, Nuneaton.
Bailes, T., Jesmond Gardens, Newcastle-upon-Tyne.
Bailey, Archibald Duncan, c/o S. G. Bailey and Company, Limited, Stafford Mills, Stroud, Gloucestershire.
Bailey, E. J., 55, Temple Row, Birmingham.
Bailey, Edward Trenholm, Mining Engineer, Sandakan, British North Borneo.
*Bailey, Samuel, 55, Temple Row, Birmingham.
Bain, James, The Whins, Alloa, N.B.
Bainbridge, Emerson, 4, Whitehall Court, London, S.W.
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Baird, Dugald, Radcliffe Colliery, Acklington, Northumberland.
Baird, James, Auchincruive Coal Company, Prestwick, R.S.O., Ayrshire.
Baird, Matthew B., West House, Bothwell, N.B.
Baird, Robert, 53, Bothwell Street, Glasgow.
Baker, Walter J., Byron Chambers, Market Place, Nottingham.
Balfour, J. L., c/o H. H. Bourne, Lindley, Stechford, Birmingham.

Ballard, R., Menzies, Western Australia.
Ballingal, Neil, Sweet Bank, Markinch, N.B.
Bancroft, Robert E., 8, St. James' Square, Manchester.
Banham, E. G., Barrow Collieries, Barnsley.
Banks, Thomas, 60, King Street, Manchester. *Transactions* to be sent to 17, Park Avenue, Eccles, near Manchester.
Bannister, David, Shawcross, near Dewsbury.
Barber, T. P., Lamb Close House, Eastwood, near Nottingham.
Barber, William, Great Fenton Collieries, Stoke-upon-Trent.
Barker, M. W., 110, Stapleton Hall Road, Stroud Green, London, N.
Barnard, A. H., Russell Cottage, Cannock, Staffordshire.
Barnard, Robert, The Retreat, Sitrampore P.O., Bengal, India.
Barnes, Alfred, Ashgate Lodge, Chesterfield.
Barnes, A. G., Tupton Hall, Chesterfield.
Barnes, A. T. H., Grassmoor Collieries, Chesterfield.
Barr, David, Lota, Chili.
Barr, Peter G., Machanhill House, Larkhall, R.S.O., Lanarkshire.
Barr, Thomas H., 10, Bothwell Street, Glasgow.
Barraclough, Samuel, Union Foundry, Barnsley.
Barrett, C. R., Whitehill Hall, Chester-le-Street.
Barron, Thomas, Barnsley Main Colliery, Barnsley.
Barrowman, James, Staneacre, Hamilton, N.B.
Bartholomew, C. W., Blakesley Hall, near Towcester.
Barwell, W. H., Fence Cottage, near Sheffield.
Bateman, James T., Fairview, Bebington, near Birkenhead.
Bates, Sidney, Mickley Colliery Offices, Stocksfield-upon-Tyne.
Bates, Thomas, The Grange, Prudhoe-upon-Tyne.
Bates, Thomas L., Hamilton, Newcastle, New South Wales.
Batey, John, Newbury Collieries, Coleford, Bath.
Batty, W., Darley Grove, Worsbro' Dale, Barnsley.
Baumgartner, W. O., Sycamore Terrace, Haswell, Sunderland.
Bawden, James Barnet, Pillar House, Keswick, Cumberland.
Bayldon, Daniel Henry, New Zealand Mines Trust, Limited, Mutual Life Buildings, Martin Place, Sydney, New South Wales.
*Beard, A., Carlton Villa, Carlton, near Barnsley.
*Becher, Septimus J., Geological Survey Office, Perth, Western Australia.
Beech, Noel Tench Lilleshall Collieries, St. Georges, Wellington, Salop.
Behrens, Herr Bergrath, Hibernia Company, Herne, Westphalia.
Beith, Robert, Lassodie Mill Colliery, Blairadam, Fifeshire.
Bell, Alan D., Bonne Terre, St. Francois County, Missouri, U.S.A.
Bell, George Fred, H.M. Inspector of Mines, 20, Wentworth Place, Newcastle-upon-Tyne.
*Bell, James, The Lührig Appliances, Limited, 32, Victoria Street, London, S.W.
Bell, Sir Lowthian, Bart., Rounton Grange, Northallerton.
Bell, Walter, c/o Pyman, Bell and Company, Hull.
Bennett, Alfred H., Dean Lane Collieries, Bedminster, Bristol.
Bennett, John, 3, Babworth Road, Retford.
Bennett, J. T., Silkstone and Haigh Moor Collieries, Allerton Bywater, Castleford.
Benson, James R., South Longrigg Colliery, Netherburn, Hamilton, N.B.
Benson, J. G., 12, Grey Street, Newcastle-upon-Tyne.
Benson, T. W., 24, Grey Street, Newcastle-upon-Tyne.
Benson, W. A., Silverdale, Staffordshire.
Beringer, R. E., Highway, Illogan, Redruth, Cornwall.
Berkley, C., Marley Hill, Swalwell, R.S.O., Co. Durham.
Berkley, Frederick, Hamsterley Colliery, Ebchester, R.S.O., Co. Durham.
Berkley, R. W., Marley Hill, Swalwell, R.S.O., Co. Durham.
Beswick, Robert, Chell Collieries, Tunstall, Staffordshire.
Bever, Augustus, Dewsbury Foundry, Dewsbury.
Beveridge, James, Linlithgow Oil Company, Linlithgow, N.B.
Beynon, J. C. S., P.O. Box 1364, Johannesburg, Transvaal.
Bibby, William, The Raub Australian Gold Mining Company, Limited, Raub, Pahang, Malay Peninsula.
Bigg-Wither, H., The Mount, Gathurst, near Wigan.
Bigland, J., Henknowle, Bishop Auckland.

Bingley, John, Bolsover Colliery, near Chesterfield.
Binns, G. J., Duffield House, Duffield, Derby.
Birrell, William, Donibristle Colliery, Crossgates, R.S.O., Fifeshire.
Bishop, George A., Gartverrie Fireclay Works, Glenboig, Coatbridge, N.B.
Bishop, James, Grey Valley Coal Company, Brunnerton, Greymouth, New Zealand.
Black, Donald.
Black, W., Lovaine House, Lovaine Place, Newcastle-upon-Tyne.
Blackburn, W. Stevenson, Aire Villas, Astley, Woodlesford, near Leeds.
Blackett, W. C., Acorn Close, Sacriston, Durham.
Blackwood, James, Scott Street, Hamilton, N.B.
Blakemore, W., Fernie, British Columbia, Canada.
Blane, James, P.O. Box 435, Johannesburg, Transvaal.
Blane, Robert, P.O. Box 435, Johannesburg, Transvaal.
Blane, W., P.O. Box 435, Johannesburg, Transvaal.
Blyth, Archibald, Park Road, Hamilton, N.B.
Boam, S. T., Whitwick Colliery, Coalville, Leicestershire.
Bolam, Philip, Seaton Burn Colliery, Newcastle-upon-Tyne.
Bolton, Edgar Ormerod, Executor of Colonel Hargreaves, Colliery Offices, Burnley.
Bolton, H. H., Newchurch Collieries, near Manchester.
Bonser, Harold, 39, Hanover Square, Leeds.
Bonthrone, Barclay, Newton House, Falkland, Fife.
Booker, E. E., Bond's Main Colliery, Temple Normanton, Chesterfield.
Borlase, W. H., Greenside Lodge, Glenridding, near Penrith.
Borrowman, James, Armadale Station, Linlithgowshire.
Boit, Samuel J., The Villas, Stoke-upon-Trent.
Boucher, A. S., Kempsey House, near Worcester.
Boulden, F., Technical Department, University College, Sheffield.
Boulton, William, Burslem, Stoke-upon-Trent.
Bowen, J., Broad Street. Bilston.
Bowie, Hunter, Lugar Iron Works, Old Cumnock, N.B.
Bowie, Kenneth McK., Priory Hill House, Canonbie, N.B.
Bowie, W. T., 90, Dobbie's Loan, Glasgow.
Bowman, Andrew H., McClure Coke Company, Scottdale, Westmoreland County, Pennsylvania, U.S.A.
Bowman, Archibald, Jun., Percival Cottage, Buckhaven, Fife.
Boyd, Adam A., Broken Hill Proprietary Company, Broken Hill, *via* South Australia.
Bradford, George, Newton House, Darlington.
Bragge, G. S., Granville Colliery, Swadlincote, Burton-upon-Trent.
Brain, F., Trafalgar House, Drybrook, Gloucester.
Bramley, George, Clay Cross Works, Chesterfield.
Bramwell, Hugh. Great Western Colliery, near Pontypridd, Glamorganshire.
Brancker, Richard, The Pearson and Knowles Coal and Iron Company, Limited, 11, Old Hall Street, Liverpool.
Brand, Mark, Bar-hill Cottage, Twechar, Kilsyth, Glasgow.
Braschi, Victor M., Bajos de Portacoeli, No. 11, Apartado, 830, City of Mexico, Mexico.
Breakell, Thomas, Brassington, near Derby.
Brealey, Arthur, Castle View, Conisboro', Rotherham.
Breckon, J. R., 53, John Street, Sunderland.
Breidenbach, Theo., The Toronto and Western Mines Development Company, Limited, Sirdar Mine, P.O. Box 151, Rat Portage, Ontario, Canada.
Brewer, William Morten, 28, Broad Street, P.O. Box 130, Victoria, British Columbia.
Brewis, George, Boythorpe Colliery, Chesterfield.
Brierley, Brandon Talfourd, Bellayre, Lymm, Cheshire.
Briggs, Herbert, Oakhill, Stoke-upon-Trent.
Britten, T. J., P.O. Box 494, Johannesburg, Transvaal.
Britton, Arthur, The St. Helen's Collieries Company, Limited, St. Helen's, Lancashire.
Brodhurst, Bernard Lucas, Glapwell Colliery, Chesterfield.
Broja, Geheimer Bergrath Richard, 77, Kaiser-Wilhelmstrasse, Breslau, Germany.

Bromly, A. H., 18, Eldon Street, London, E.C.
Broom, Robert, Kirkwood Colliery, Bargeddie, N.B.
Broome, George Herbert, The Westport Cardiff Coal Company, Limited, Seddonville, *via* Westport, New Zealand.
Brough, Bennett H., Cranleigh House, Woodham, near Addlestone, Surrey.
Brough, Thomas, New Seaham Colliery, Sunderland.
Brown, Adam, Allanton Colliery, Hamilton, N.B.
Brown, A. T., 372, Flinders Lane, Melbourne, Australia.
Brown, Douglas Philip, Oakley, Carysfort Road, Boscombe.
Brown, E., St. John's Colliery, Normanton.
Brown, Fred., 57, Bridge Street, Walsall.
Brown, George, Longriggend Colliery, Airdrie, N.B.
Brown, Myles, Nirshachetty P.O., Shampore, *via* Barakar, E.I.R., Bengal, India.
Brown, M. **Walton**, 10, Lambton Road, Newcastle-upon-Tyne.
*__Brown, Thomas__, Westport Coal Company, Millerton, Westport, New Zealand.
Brown, Thomas Forster, Guildhall Chambers, Cardiff.
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Brown, Westgarth F., Fairview, Dynas Powis near Cardiff.
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Russell, W. S., Cameron Cottage, by Airdrie, N.B.
Rutherford, W., South Derwent Colliery, Annfield Plain, Lintz Green.

Saint, **William**, H.M. Inspector of Mines, Kersal Bank, Higher Broughton, Manchester.
Salmond, **James**, Barncluith Colliery, Hamilton, N.B.
Salmond, **Walter**, Pinxton Collieries, Alfreton.
Sam, T. B. F., c/o F. and A. Swanzy, Cape Coast Castle, West Africa.
Samborne **John Stukely Palmer**, Timsbury House, Bath.
Sandeman, **John** J., Allan House, Rossland, British Columbia.
***Saner**, C. T., Rietfontein A, Limited, per Private Bag, Johannesburg, Transvaal.
Sankey, W. H., Morley Hall, Derby.
Satterthwaite, **John**, Garbham Mines, Garividi, E.C.R., Vizagapatam District, India.
Saunders, **David William Alban**, Worcester Chambers, Swansea.
Saunders, **William Thomas**, Ivydene, West Cross, R.S.O., near Swansea.
Savage, **Arthur Thomas Chambers**, Cossall Collieries, Nottingham.
Sawyer, A. R., c/o Fletcher's Wholesale, Cape Town, South Africa; and Hilhouse, Woking, Surrey.
Schmitz-Dumont, G., Inspector of Mines, Barberton, Transvaal.
Schroller, **William**, c/o Simon-Carves Bye-Product Coke Oven Construction and Working Company, Limited, 20, Mount Street, Manchester.
Schultz, Dr. **Bergrath**, Bergschule, Bochum, Prussia, i.w.
Scott, C. F., Grove Cottage, Leadgate, Co. Durham.
Scott, **Elgin**, Ropienka Oil Wells, Ropienka, Galicia, Austria.
Scott, **Ernest**, Close Works, Newcastle-upon-Tyne.
Scott, E. **Charlton**, 20, Henrietta Street, Swansea.
Scott, F. **Bowes**, 2 and 3, Birch Lane, London, E.C.
Scott, F. W., Atlas Wire Rope Works, Reddish, Stockport.
Scott, **Joseph**, Ngahire, *via* Greymouth, New Zealand.
Scott, J. S., Trimdon Hall, Trimdon Grange, R.S.O., Co. Durham.
Scott, **William**, Thornhill Collieries, near Dewsbury.
Scoular, G., St. Bees, Cumberland.
Scrivener, **Edward** E.
Seely, Sir **Charles**, Bart., Sherwood Lodge, Arnold, Notts.
Seely, C. H., Sherwood Lodge, Arnold, Notts.
Selby, **John Baseley**, Leigh, Lancashire.
Selkirk, **James Gunsen**, Dalton-in-Furness.
Sellers, **Alfred Ernest Oswald**, Metropolitan Colliery, Helensburgh, New South Wales.
Senior, A., Birk House, Barnsley.
Settle, **Joel**, The Hill, Alsager, Stoke-upon-Trent.
Settle, **Joseph Burton**, The Bartissol Gold Mining Company, Limited, Umtali, Rhodesia, South Africa.
Settle, W., Darcy Lever Collieries, near Bolton.
Seymour, L. **Irving**, c/o Rand Mines, Limited, c/o Maxwell and Earp, P.O. Box 538, Cape Town, South Africa.
Sharp, **Jacob**, Burnmoor Colliery, Fence Houses.
Shaw, F. G.
Shaw, G., Wath Main Colliery, Rotherham.
Shaw, **John**, Isle Cottage, Muirkirk, N.B.
Shaw, **John**, Welburn Hall, Kirby Moorside, R.S.O., Yorkshire.
Shaw, J. **Leslie**, Somerset House, Whitehaven.
Shearer, A. W., Pottsville, Pennsylvania, U.S.A.
Sheard, R., Caldervale Boiler Works, Wakefield.
Shearer, **James** A., Earnock Colliery, Hamilton, N.B.
Shenton, **James**, Ross Cottages, Edward Street, West Bromwich.
Shiel, **John**, Framwellgate Colliery, Co. Durham.
Shore, **Thomas**, Shag Point Colliery, Otago, New Zealand.
Short, W., Lambton Colliery, Newcastle, New South Wales.
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Silvester, **Fred**., Newcastle, Staffordshire.
Simon, **Frank**, c/o The African Banking Corporation, Limited, Durban, Natal, South Africa.

SIMPKIN, ARTHUR, Pildacre Collieries, Ossett, near Wakefield.
SIMPKIN, J. W., Midsomer Norton, Bath.
SIMPSON, C. L., Engine Works, Grosvenor Road, Pimlico, London.
SIMPSON, F. L. G., Mohpani Coal Mines, Gadawarra, C.P., India.
SIMPSON, F. R., Hedgefield House, Blaydon-upon-Tyne.
SIMPSON, GILBERT PITCAIRN, 3, Cornwall Terrace, Regent's Park, London, N.W.
SIMPSON, J., Heworth Colliery, Felling, R.S.O., Co. Durham.
SIMPSON, J. B., Bradley Hall, Wylam-upon-Tyne.
SIMPSON, ROBERT, 95, Bath Street, Glasgow.
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SKINNER, SAMUEL, Throapham Manor, Rotherham.
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*SMALLMAN, REUBEN, Camp Hill Grange, Nuneaton.
SMART, A., c/o Frazer and Chalmers, Limited, Erith, Kent.
SMELLIE, ARCHIBALD, Bank Colliery, New Cumnock N.B.
SMITH, ALEXANDER, 238, West George Street, Glasgow.
SMITH, ALEXANDER, 3, Newhall Street, Birmingham.
SMITH, ALFRED GODDEN, Golden Valley Ochre and Oxide Company, Wick, Bristol.
SMITH, C. SEBASTIAN, Shipley Collieries, Derby.
SMITH, DAVID, Dalmellington Iron Works, Ayr, N.B.
SMITH, DAVID CURLE, Little Sylvester Street, Coolgardie, Western Australia.
SMITH, DALZIEL GORDON, P.O. Box 21, Vancouver, British Columbia.
SMITH, DAVID L.
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SMITH, GEORGE W., Port Elizabeth, South Africa.
SMITH, H., North Side, Queen's Dock, Hull.
SMITH, H. S., Timsbury Collieries, near Bath.
SMITH, JOHN, Bickershaw Collieries, Leigh, Lancashire.
SMITH, J. BAGNOLD, Westfield House, Sutton-in-Ashfield, Nottinghamshire.
SMITH, R. CLIFFORD, Ashford Hall, Bakewell.
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SMITH, WILLIAM, Dalmellington Iron Works, Ayr, N.B.
SMITH, W. IVAN, Sydney Villa, Blackheath, Dudley, Worcestershire.
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SNEDDON, JAMES B., Oakbank Colliery, Mid-Calder, N.B.
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SOAR, EDWARD, Kiveton Park Colliery, Sheffield.
SOAR, H. G., Frystone Collieries, Castleford.
SOAR, M., Warren, Chapeltown, Sheffield.
SOMERVILLE, W. W.
SOPWITH, ARTHUR, Cannock Chase Collieries, near Walsall.
SOUTHALL, WILLIAM, Park Hall Colliery, Cheadle, Staffordshire.
SOUTHERN, E. O., Ashington Colliery, near Morpeth.
SOUTHERN, JOHN, Heworth Colliery, Newcastle-upon-Tyne.
SOUTHERN, R., Burleigh House, The Parade, Tredegarville, Cardiff.
SOUTHERN, T. A., The Universal Mining School, Cardiff.
SOUTHWORTH, THOMAS, Hindley Green Collieries, near Wigan.
SPARGO, EDMUND, 3, Cable Street, Liverpool.
SPARKES, J. S., 55, Richmond Road, Cardiff.
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SPENCE, R. F., Backworth, R.S.O., Northumberland.
SPENCER, E. D., 120, Southfields, Leicester.
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SPENCER, GEORGE, Stanley Lodge, West Hallam, Derby.

Spencer, J., Globe Tube Works, Wednesbury.
Spencer, John, Westgate Road, Newcastle-upon-Tyne.
Spencer, J. W., Newburn, near Newcastle-upon-Tyne.
Spencer, Richard, Hanover Square, Leeds.
Spencer, T., Ryton, Newcastle-upon-Tyne.
Spencer, William, Southfields, Leicester.
Spooner, George, Darfield Main Colliery, near Barnsley.
Squire, J. B., Thrale Hall, Streatham, Surrey.
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Standley, William, Glenroy, Nuneaton.
Stanier, Francis, Peplow Hall, Salop.
Stanley, Reginald, Stanley's Engineering Company, Nuneaton.
Stansfeld, Harold Sinclair, Jordan Colliery, Limited, near Rotherham.
Stanton, John, 11 and 13, William Street, New York, U.S.A.
Statham, William, Field House, Chesterton, Newcastle, Staffordshire.
Stear, J., Strafford Colliery, Barnsley.
Steavenson, A. L., Durham.
Steavenson, C. H., Redheugh Colliery, Gateshead-upon-Tyne.
Steele, Richard, Hanley, Staffordshire.
Stevens, A. J., Uskside Iron Works, Newport, Monmouthshire.
Stevenson, Henry, Linby Colliery, Nottingham.
Stevenson, Hugh, 13, Carlton Place, Glasgow.
Stevenson, Thomas, Earnock Colliery, Hamilton, N.B.
Stevenson, William, Belhaven and Clydesdale Collieries, Wishaw, N.B.
Stewart, Alexander, c/o Broken Hill Proprietary Company, Limited, Broken Hill, *via* Adelaide, New South Wales.
Stewart, W., Powells Tillery Steam Coal Company, Limited, Abertillery, Monmouthshire.
Stobart, F., Biddick Hall, Fence Houses.
Stobart, H. T., Wearmouth Colliery, Sunderland.
Stobart, W., Pepper Arden, Northallerton.
Stobart, W. R., Etherley Collieries, Co. Durham.
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Stoker, Arthur P., Birtley, near Chester-le-Street.
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Stoker, Thomas E., Prospect House, Leasingthorne, Bishop Auckland.
Stone, Arthur, Heath Villas, Hindley, Wigan.
Stones, George B., Dale View, Conisborough, Rotherham.
Storey, Thomas E., Trentham, Stoke-upon-Trent.
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Strain, James M., 11, Hillend Gardens, Partickhill, Glasgow.
Straker, J. H., Howden Dene, Corbridge-upon-Tyne.
Streatfield, Hugh S., Ryhope, near Sunderland.
Strick, John, Bar Hill, Madeley, Staffordshire.
Stuart, Donald M. D., Redland, Bristol
Stubbs, Thomas, Aldwarke Main Colliery, Rotherham.
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Sumnall, Henry, High Carr Collieries, Chesterton, near Newcastle, Staffordshire.
Sutton, William, Newstead Hall, near Wakefield.
Swallow, J., Catchgate, Annfield Plain, R.S.O., Co. Durham.
Swallow, J. F., Mosboro' Hill House, Eckington, Sheffield.
Swallow, R. T., Simonside House, Simonside, South Shields.
Swan, H. F., North Jesmond, Newcastle-upon-Tyne.
Swan, J. G., Upsall Hall, near Middlesbrough.
Swann, Hugh P., Gartcraig, Shettleston, N.B.
Swift, Robert Mountain, Sim Hill, Cranemoor, near Sheffield.
Swinney, Alfred John George, Lorne Villa, Elm Road, Sidcup, Kent.
Symons, Francis, Ulverston, Lancashire.

Tate, Simon, Trimdon Grange Colliery, Co. Durham.
Tatham, Frank, Coleorton Colliery, Ashby-de-la-Zouch.
Tattley, William, Taupiri Coal Mines, Limited, Huntly, Waikato, New Zealand.

Tatum, Lawrence W., Dolores Hidalgo, Guanajuato, Mexico.
Taylor, Hugh, East Holywell Office, Quayside, Newcastle-upon-Tyne.
Taylor, T., Quay, Newcastle-upon-Tyne.
Teasdale, T., Middridge, *via* Heighington, R.S.O.
Telfer, Henry, Jun., Clydesdale, Uddingston, N.B.
Telford, W. H., Hedley Hope Collieries, Tow Law, R.S.O., Co. Durham.
Tennent, Robert, H.M. Inspector of Mines, Westport, New Zealand.
Terris, Henry, Clackmannan Colliery, Clackmannan, Alloa, N.B.
Thirkell, E. W., Oaks Colliery, Barnsley.
Thom, James R., Balbardie Colliery, Bathgate, N.B.
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Thomas, J. J., Hawthorn Villa, Kendal.
Thomas, R., Bloxwich, Walsall.
Thomas, Reginald.
Thomas, Richard, Brown's Duckinfield Collieries, Minmi, Newcastle, New South Wales.
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Thompson, John William, Greenfield House, Crook, R.S.O., Co. Durham.
Thompson, Thomas, Park Mill Colliery, Clayton West, Huddersfield.
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Thomson, A. S., Brahmin Bararee, Jherriah P.O., District Manbhoom, Bengal, India.
Thomson, George, Bannockburn Colliery, Bannockburn, R.S.O., Stirlingshire.
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Thomson, James, Ross Street, Dunfermline, N.B.
Thomson, John, Glenarm Lime Works, Larne, Co. Antrim.
Thomson, John, Eston Mines, by Middlesbrough.
Thomson, Joseph F., Manvers Main Colliery, Wath-upon-Dearne, Rotherham.
Thomson, R. D., Ibstock Colliery, Leicester.
Thomson, Thomas, Eddlewood Colliery, Hamilton, N.B.
Thornewill, Robert, Engineering Works, Burton-upon-Trent.
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Tinker, J. J., Hyde, Manchester.
Todd, John T., Blackwell Collieries, Alfreton.
Todd, W. G., 69, Norfolk Road, Sheffield.
Tomlinson, John, Acres, Pilsley, Chesterfield.
Tonkin, J. J., Linares, Provincia de Jaen, Spain.
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Townsend, Henry George, St. John's Colliery, Normanton.
Treadwell, George A., Phœnix, Arizona, U.S.A.
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Tulip, Samuel, Bunker Hill, Fence Houses.
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Turnbull, J. J., East Indian Coal Company, Limited, Jherriah P.O., District Manbhoom, Bengal, India.
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Turner, David Neville, Mansfield Woodhouse, Mansfield.
Turner, George, Buxton House, Holyhead Road, Handsworth, Birmingham.
Turner, John, Moira Colliery, Ashby-de-la-Zouch.
Turner, Samuel, William Pit, Whitehaven Collieries, Whitehaven.
Turner, T. A., Aldwarke, Rotherham.
Turner, T. N., Langley Mill, Notts.

Turner, William Jepson, The Chase, Charnwood, Whitwick, Leicester.
Twist, Thomas, Steps House, Kidsgrove, Staffordshire.
Tyas, A. R., Swaithe, near Barnsley.
Tyers, John E., c/o The Hyderabad Deccan Company, Limited, Secunderabad, Deccan, East India.
Tyzack, David, Bellingham, Northumberland.

Upton, Prescott, P.O. Box 1026, Johannesburg, Transvaal.

Vallance, William, Ross Colliery, Ferniegair, Hamilton, N.B.
Varty, Thomas, Skelton Park Mines, Skelton, R.S.O., Cleveland.
Vaughan, Cedric, Hodbarrow Iron Ore Mines, Millom, Cumberland.
Vaughan, John, Balaclava House, Dowlais, Glamorganshire.
Veasey, Thomas Fred., 5, Copthall Buildings, London, E.C.
Veasy, Harvey C., Burrakur Coal Company, Limited, Barakar, Bengal, India.
Verny, George, Doubovais, Balka Krivoi, Russia.
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Vivian, John, Vivian's Boring and Exploration Company, Limited, 42, Lowther Street, Whitehaven.

Waddell, Robert, Underwood, Mount Vernon, N.B.
Waddle, H., The Waddle Patent Fan and Engineering Company, Limited, Llanelly, South Wales.
Wade, Robert Armytage, Annesley, Nottingham.
Wadham, E., Millwood, Dalton-in-Furness.
Wadsworth, William Deakin, Jun., New Square, Chesterfield.
*Wagner, John R., The Cross Creek Coal Company, Drifton, Luzerne County, Pennsylvania, U.S.A.
Wain, Edward B., Whitfield Collieries, Norton-in-the-Moors, Stoke-upon-Trent.
Wain, J. R., Chatterley-Whitfield Collieries, Tunstall, Staffordshire.
Wales, H. T., Western Mail Chambers, Cardiff.
Walker, David M., Prospect Villa, Lenzie, Glasgow.
Walker, George Blake, Wharncliffe Silkstone Colliery, Barnsley.
Walker, Henry Blair, Die Rietfontein Colliery, Springs, Johannesburg, Transvaal.
Walker, J. S., Pagefield Iron Works, Wigan, Lancashire.
Walker, Peter.
Walker, Sydney F., Bloomfield Crescent, Bath.
Walker, Thomas A., Pagefield Iron Works, Wigan.
Walker, W., Hawthorns, Saltburn-by-the-Sea.
Walker, William, Digby Collieries, near Nottingham.
Walker, William, Cadzow Colliery, Hamilton, N.B.
Walker, William, Jun., H.M. Inspector of Mines, Durham.
Walker, W. E., Manners Colliery, Ilkeston.
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Wallace, J., King Street, Wigan.
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Walton, J. Coulthard, Writhlington Colliery, Radstock, *via* Bath.
Walton, Thomas, Habergham Colliery, Burnley.
Walton, W. W., Croft Cottage, Ferryside, near Carmarthen, South Wales.
Wanless, Bateman, Garforth Colliery, Leeds.
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Ward, F. L., Bradford Colliery, Bradford, Manchester.
Ward, H., Rodbaston Hall, near Penkridge, Stafford.
Ward, T. H., Giridih, E.I.R., Bengal, India.
Wardell, Harry, Rockingham Colliery, near Barnsley.
Wardell, S. C., Doe Hill House, Alfreton.
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Watkyn-Thomas, W., Workington.
Watson, Andrew, Cadzow Colliery, Hamilton, N.B.
Watson, Edward, South Pelaw Colliery, Chester-le-Street.
Watson, Simeon, New Hucknall Colliery, Mansfield.
Watson, T., Trimdon Colliery, Trimdon Grange.
Watson, William, Annesley, Uddingston, Glasgow.
Watson, William, Livingstone Terrace, Uddingston, Glasgow.
Watts, John, Mossfield Colliery, Longton, Staffordshire.
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Webster, David, Burdiehouse Limeworks, Loanhead, Midlothian.
Webster, Francis, c/o W. Macintyre, Warwick Villa, Dandinong, Victoria, Australia.
Webster, H. Ingham, Mainsforth Hall, Ferry Hill, S.O., Co. Durham.
Weeks, J. G., Bedlington, R.S.O., Northumberland.
Weeks, R. L., Willington, Co. Durham.
Weinberg, Ernest Adolph, The Smelting Company of Australia, Limited, Dapto, New South Wales.
Weir, Alexander, Fireclay Works, Castlecary Station, Glasgow.
*Weir, Robert, Camp Colliery, Motherwell, N.B.
Weir, William, Blairhall Colliery, East Grange, Dunfermline, N.B.
Wemyss, R. E., Wemyss Castle, Fifeshire.
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Westmacott, P. G. B., Rose Mount, Sunninghill, Berks.
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White, H., Walker Colliery, Newcastle-upon-Tyne.
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White, J. F., 15, Wentworth Street, Wakefield.
*Whitehead, John, Ashleigh, Buxton.
Whitehouse, W. H., Brownhills, Walsall.
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Whitelaw, Thomas, 112, Wellington Street, Glasgow.
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Whyte, Robert, Clyde Wire Rope Works, Rutherglen, Glasgow.
Wickett, F., Clinton Road, Redruth, Cornwall.
Widdas, C., North Bitchburn Colliery, Howden, Darlington.
Wight, Edward S., Mount Kembla Colliery, Wollongong, New South Wales.
Wight, W. H., Cowpen Colliery, Blyth.
Wilcox, H., Miners' Safety Explosive Works, Stanford-le-Hope, Essex.
Wilde, W., Hickleton Main Colliery, Thurnscoe, Rotherham.
Wilde, William, Brockett House, Sharrow, Sheffield.
Wilkes, John S., Pelsall Foundry, Walsall.
Wilkie, Neil A., Nethercroft Mines, Croy, Glasgow.
Wilkins, William Glyde, Westinghouse Building, Pittsburg, Pennsylvania, U.S.A.

Wilkinson, Horace, West Hallam, near Derby.
Wilkinson, J. R., Spark Lane, Mapplewell, Barnsley.
Wilkinson, Thomas, Tinsley, near Sheffield.
Wilks, Arthur, Batman's Hill House, Bradley, Bilston.
Williams, Edmund W., The High Carr Ironstone Works, Chesterton, Staffordshire.
Williams, Ernest, c/o Bewick, Moreing and Company, A.M.P. Buildings, St. George's Terrace, Perth, Western Australia.
Williams, Gardner F., De Beers Consolidated Mines, Limited, Kimberley, South Africa.
Williams, Herbert Ignatius, The Old Rectory, Scholar Green, Stoke-upon-Trent.
Williams, H. J. Carnegie, c/o J. McDonald, 43, Threadneedle Street, London, E.C.
Williams, Luke, Mount Reid Mining Company, Limited, Mount Read, Tasmania.
Williams, Richard, The Johnsons Reef Gold Mines Company, N.L., California Gulley, Bendigo, Victoria, Australia.
Williams, Robert, 30, Clement's Lane, Lombard Street, London, E.C.
Williams, Samuel Herbert, Newfoundland Iron Ore Company, Workington, Lower Island Cove, Newfoundland.
Williamson, J., The Hills, Cannock, Staffordshire.
***Williamson, J. H.**, Henshall House, Goldenhill, Stoke-upon-Trent. *Transactions* to be sent to the Representatives of the late J. H. Williamson, The High Carr Ironstone Works, Chesterton, Staffordshire.
Williamson, R., The Denaby and Cadeby Main Colliery Offices, Conisborough, near Rotherham.
Williamson, R. S., Cannock Wood House, Hednesford, Staffordshire.
Williamson, Thomas, West Hallam Collieries, Ilkeston.
Williamson, William, Opal Cottage, Burnblea, Hamilton, N.B.
Wilson, Archibald Lawrence, The New Ravenswood Limited, Ravenswood, Queensland, Australia.
Wilson, Arthur P., Mansion House Chambers, Queen Victoria Street, London, E.C.
Wilson, Benjamin, Ingleton Colliery, Ingleton, Kirby Lonsdale.
Wilson, David, Wester Gartshore Colliery, Kirkintilloch.
Wilson, George, Blairadam Colliery, Kelty, Fifeshire.
Wilson, John, 397, Harewood Street, Bradford.
Wilson, John, Espieside Colliery, Coatbridge, N.B.
Wilson, John, 75, Bothwell Street, Glasgow.
Wilson, J. B., The Rowans, Ashley Road, Epsom.
Wilson, John R. Robinson, H.M. Inspector of Mines, 1, St. Mary's Road, Newton Park, Leeds.
Wilson, Joseph R., 138, East Washington Lane, Germantown, Philadelphia, Pennsylvania, U.S.A.
Wilson, Lloyd, Flimby Colliery, Maryport.
Wilson, P. O.
Wilson, Robert, Bathville Collieries, Armadale, N.B.
Wilson, W. B., Hawthorn Rectory, Sunderland.
Wilson, W. E. C., Exhall Colliery, Bedworth, near Nuneaton. *Transactions* to be sent to the Gables, Bedworth, near Nuneaton.
Winchell, Horace V., Butte, Montana, U.S.A.
Wingate, John B., 208, St. Vincent Street, Glasgow.
Winstanley, Peter, Shaw Cross Colliery, near Dewsbury.
Winstanley, Robert, 28, Deansgate, Manchester.
Withers, Charles, 65, Station Street, Nottingham.
Witty, H. Sykes, Denaby Main House, near Rotherham.
Wolstenholme, M., Llanfoist House, near Abergavenny.
Wood, C. L., Freeland, Forgandenny, Perthshire.
Wood, E. S., c/o Bengal Coal Company, Limited, 5, Fairlie Place, Calcutta, India.
Wood, James, 28, Royal Exchange Square, Glasgow.
Wood, John, Coxhoe Hall, Coxhoe, R.S.O., Co. Durham.
Wood, Jno., Barley Brook Foundry, Wigan.
Wood, Sir Lindsay, Bart., The Hermitage, Chester-le-Street.
Wood, Robert Arna, c/o Harrison, Barber and Company, Limited, 18, Queen Victoria Street, London, E.C.

Wood, Thomas, North Hetton Colliery Office, Moorsley, Hetton-le-Hole, R.S.O.
Wood, W. H., Coxhoe Hall, Coxhoe, R.S.O., Co. Durham.
Wood, Walter K., Broomhouse Colliery, Broomhouse, Glasgow.
Wood, W. O., South Hetton, Sunderland.
Woodall, William, Bleak House, Burslem, Stoke-upon-Trent.
Woodburn, J. Allan, Rezende, Limited, Penhalonga, Umtali, Rhodesia, British South Africa.
Woodburne, T. J., De Beers Consolidated Mining Company, Limited, Kimberley, South Africa.
Woodhead, Alfred, Low Moor Iron Works, Bradford.
Woodhead, L., Beeston Colliery, Leeds.
Woods, Richard, Seymour Colliery, Staveley, Chesterfield.
Woodward, Harry P., 59, Irwin Street, Perth, Western Australia. *Transactions*, etc., to be addressed to 129, Beaufort Street, Chelsea, London, S W.
Woodworth, Benjamin, Heron Cross, Fenton, Stoke-upon-Trent.
Woolcock, J. H., 49, Lowther Street, Whitehaven.
Wordsworth, Robert, Warora Colliery, Central Provinces, India.
Wordsworth, T. H., New Moss Colliery, Audenshaw, near Manchester.
Wormald, C. F., Mayfield Villa, Saltwell, Gateshead-upon-Tyne.
Worth, F. G., 63, Queen Victoria Street, London, E.C.
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Wright, Joseph, Arboretum Street, Nottingham.
Wrightson, T., Stockton-upon-Tees
Wroe, James, Croft House, Featherstone, Pontefract.
Wynne, Thomas Trafford, c/o W. Watkyn Wynne, c/o T. Sherratt and Nelson, Solicitors, Kidsgrove, Staffordshire.
Wroe, Jonathan, Wharncliffe Silkstone Colliery, Barnsley.
Wyper, James, Townlands Colliery, Hamilton, N.B.
Wysehall, George E., 53, Shirland Lane, Attercliffe, Sheffield.

Young, Henry William, Greymouth, New Zealand.
Young, James, 4, Granville Road, Jesmond, Newcastle-upon-Tyne.
Young, John, Baljaffray Colliery, Bearsden, Glasgow.
Young, John A., 3, Fountain Avenue, Gateshead-upon-Tyne.
Young, J. H., Wearmouth Colliery, Sunderland.
Young, Robert, Tacoma, Washington, U.S.A.

Zumbuloglon, G. C., Mahmoudie-Han, Stamboul, Turkey.

Associate Members.

Assoc.M.Inst.M.E.

* Deceased.

Anderson, J. Scott, 53, Waterloo Street, Glasgow.
Appleyard, Henry, c/o W. Firth, Water Lane, Leeds.
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Armstrong, J. H., St. Nicholas' Chambers, Newcastle-upon-Tyne.
Armstrong, T. J., Hawthorn Terrace, Newcastle-upon-Tyne.
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Banks, Charles John, Westwood, Washington, R.S.O., Co. Durham.
Bell, Hugh, Middlesbrough-upon-Tees.
Bigge, Edward Ellison, General Mining Association, Dashwood House, 9, New Broad Street, London, E.C. *Transactions*, etc., to be sent to R. H. Brown, Sydney Mines, Cape Breton, Nova Scotia.
Blenkiron, J. Ernest, 3, Albert Terrace, Middlesbrough-upon-Tees.
Blow, A. A., The Sheba Gold Mining Company, Limited, Eureka City, Barberton, Transvaal.
Blue, A., Bureau of Mines, Toronto, Ontario, Canada.
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Cockburn, W. C., 9, Alexandra Place, Newcastle-upon-Tyne.
Collopy, Lieut. Charles J., C Squadron, Bethune's Mounted Infantry, Tugela Ferry, Natal.
Cooper, R. W., Newcastle-upon-Tyne.
Cory, Clifford J., c/o Cory Brothers and Company, Limited, Cardiff.
Court, Josiah, Staveley, Chesterfield.
Cox, Percy Mottram, Stoke-upon-Trent.
Cullen, W., The Thames, Stanford-le-Hope, Essex.

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Davenport, J. E., Black Bull Street, Leeds.
Davies, D. H., Solicitor, Chesterfield.
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Gilbert, William J., Monarch Gold Mining Company, Gullewa, *via* Yalgoo, Murchison, Western Australia.
Graham, John, Findon Cottage, Sacriston, Durham.
Gregson, Jesse, Australian Agricultural Company, Newcastle, New South Wales.
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Henderson, C. W. C., The Riding, Hexham.
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Heppell, W. J., Cwmaman Colliery, Aberdare, South Wales.
Heyworth, Colonel Lawrence, Chadacre Hall, Bury St. Edmunds, Suffolk.
Hickman, E., Millfields Road, Bilston.
Hill, Albert J., New Westminster, British Columbia.
Hodgetts, Arthur, c/o A. H. Thornton, 82, Station Road, Handsworth, Birmingham.
Hodgson, Albert, Santa Francisca Gold Mines, Limited, Leon, Nicaragua, Central America.

Holland, Williamson, 36, Orchard Terrace, Rochdale Road, Heywood, Lancashire.
Holliday, Henry, Consett Iron Works, Blackhill, Co. Durham.
Hopper, J. I., Wire Rope Works, Thornaby-upon-Tees.
Humphreys-Davies, G., 8, Laurence Pountney Hill, Cannon Street, London, E.C.
Hunter, C. E., Selaby Park, Darlington.
Hunter, Robert, 72, Waterloo Street, Glasgow.

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Innes, Thomas Snowball, Crown Chambers, Side, Newcastle-upon-Tyne.
Irvine, J. R., Hendon Ropery, Sunderland.

James, H. M., Colliery Office, Whitehaven.
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Jeffrey, J. A., The Jeffrey Manufacturing Company, Columbus, Ohio, U.S.A.
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Kirkby, William, c/o H. C. Embleton, Central Bank Chambers, Leeds.
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Malson, W. A., Sheffield Road, Chesterfield.
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Murray, Harvey, Bank of British North America, Vancouver, British Columbia.

Newbery, Frederick, 230, Camden Road, London, N.W.

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Pringle, John, c/o Russo-Chinese Bank, Newchwang, China.
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Ramsay, Robert, Chapel Colliery, Newmains, N.B.
Richter, F., Osborne Villas, Newcastle-upon-Tyne.
Ridley, J. C., 1, Bentinck Terrace, Newcastle-upon-Tyne.
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Robinson, Walter Francis, Greymouth, New Zealand.
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Shaw, Saville, Durham College of Science, Newcastle-upon-Tyne.
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Sjögren, Hj., Osmo-Nynas, Sweden.
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Turner, Charles Edward, The Cordoba Exploration Company, Limited, Mina Cerro Muriano, Cordoba, Spain.

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Waldie, Thomas, 44, Constitution Street, Leith.
Wall, G. Young, Halmote Court Office, New Exchequer Buildings, Durham.
Walmesley, Oswald, 2, Stone Buildings, Lincoln's Inn, London, W.C.
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Wehner, Fred. C., 5 Alexandra Terrace, Stanley Road, Wallington, Surrey.
Wesley, W. H., Sen., The Anchor Tin Mine, Limited, Lottah, Tasmania.
Whitehead, Thomas, Brindle Lodge, Preston, Lancashire.
Williams, Thomas J., Moyston, Victoria, Australia.
Wood, Arthur Nicholas Lindsay, The Hermitage, Chester-le-Street.
Wood, E. P., 24, Mount Nod Road, Streatham, London, S.W.

Yates, Frederick Blakeley, 2, Mount Street, Manchester.

Associates.

Assoc.Inst.M.E.

* Deceased.

Adams, Charles, Whitfield Collieries, Norton-in-the-Moors, Stoke-upon-Trent.
Allport, E. A., 89, Dodworth Road, Barnsley, Yorkshire.

Ball, Joseph, Taquah Gold Mine, Axim, Gold Coast, West Africa.
Barber, Joseph, Ansley Hall Collieries, Atherstone.
Barrass, M., Hedley Hill Colliery, Waterhouses, Co. Durham.
Battey, Thomas, Percy Terrace, Backworth Colliery.
Beckett, James, 57, Pine Street, Teams, Gateshead-upon-Tyne.
Bedford, A., Warren Drive, Shirebrook, Mansfield.
Bell, J., Wardley Colliery, Newcastle-upon-Tyne.
Bell, Thomas, White Lea Colliery, Crook, R.S.O., Co. Durham.
Bell, W. R., Wearmouth Colliery, Sunderland.
Bentley, George, Bradford Colliery, Manchester.
Berry, Thomas, 1, Middleton, Swalwell, R.S.O., Co. Durham.

Bewick, George, Dudley Colliery, Northumberland.
Blackburn, Howard, Birley Collieries, Sheffield.
Bolam, J. T., The View, Beamish, Chester-le-Street.
Booth, Aaron, Hilcote, Blackwell, Alfreton.
Bowes, Thomas, Pontop House, Annfield Plain, R.S.O.
Bowman, Frank, Trimdon Grange Colliery, County Durham.
Bramley, William, Dale Moor, Ilkeston.
Briggs, John, Church Street, Eckington, Sheffield.
Bromley, Oliver J., Leycett, near Newcastle, Staffordshire.
Brown, R. O., Throckley Colliery, near Newcastle-upon-Tyne.
Burdett, J. C., James Street, Swadlincote, Burton-upon-Trent.
Buxton, Simeon, Clematis Cottages, Stanhope Road, Swadlincote, Burton-upon-Trent.

Calland, Robert, East Hedley Hope Colliery, Tow Law, R.S.O., Co. Durham.
Campbell, C. W., 4, Old Terrace, Muirkirk, N.B.
Carroll, John, Newfield House, Newfield, Willington, Co. Durham.
Chambers, James, 2, Noel Street, Kimberley, Notts.
Clare, Henry, Birchenwood Colliery Company, Limited, Kidsgrove, Stoke-upon-Trent.
Clark, Thomas, Dipton Colliery, Lintz Green Station.
Clay, Zechariah, New Watnall, Nottingham.
Clifford, E. Herbert.
Clough, John, 1, Melton Terrace, Seaton Delaval, R.S.O., Northumberland.
Cockburn, Edmund, High Street, Boosbeck, Skelton-in-Cleveland, Yorkshire.
Cockburn, Evan, Page Bank Colliery, *via* Spennymoor, Durham.
Corbett, Vincent, 2, Grey Terrace, Ryhope, *via* Sunderland.
Coupe, Robert, Tibshelf Collieries, Alfreton.
Cowx, H. F., Thornley Collieries, *via* Trimdon Grange, R.S.O.
Crown, William, 39, Fifth Row, Ashington, Morpeth.
Cutts, George, Lowe's Hill, Ripley, Derby.

Danks, Francis, Salsburgh, Holytown, N.B.
Danskin, Thomas, Springwell Colliery, Gateshead-upon-Tyne.
Davis, James E., South Medomsley Colliery, Dipton, R.S.O., Co. Durham.
Davison, Francis, 37, Hedley Hill Terrace, Waterhouses, Co. Durham.
Davison, Mathew, Hedley Hill Colliery, Waterhouses, Co. Durham.
Day, James, Barlborough Colliery, Clown, Chesterfield.
Daykin, George, 116, High Gurney Villa, near Bishop Auckland.
Ditmas, Francis Ivan Leslie, Ferryhill, Co. Durham.
Dormand, Ralph B., Waldridge Colliery, Chester-le-Street.
Draper, W., New Seaham Colliery, Sunderland.
Dunnett, Samuel, 20, Hambledon Street, Blyth, Northumberland.

Edwards, Paul, Talk-o'-th'-Hill Colliery, Talke, Stoke-upon-Trent.
Elliott, C. H., Wombwell Main Colliery, Barnsley.
Elliott, Daniel, Houghton Main Colliery, Barnsley.
Elliott, J. W., Kirkby Colliery, Kirkby-in-Ashfield, Nottingham.
Eltringham, George, Eltringham Colliery, Prudhoe-upon-Tyne, R.S.O.
Elves, Edward, Middridge Colliery, Heighington, R.S.O.
Emmerson, George, Brandon Colliery, near Durham.
Evans, William, Cliffe Vale, Stoke-upon-Trent.

Fawcett, Edward, Middle Street, Walker-upon-Tyne.
Ferguson, Kenneth, c/o Charles Cammel and Company, Limited, Cyclops Works, Sheffield.
Fewster, John, 4, Belgrave Terrace, Felling, R.S.O., Co. Durham.
Finch, W. W., The Lewdin Colliery Company, Worsborough Dale, Barnsley.
Finney, Joseph, Elswick Collieries, Newcastle-upon-Tyne.
Fisher, Arthur, 160, Ashton New Road, Clayton, Manchester.
Foster, J. W., Warora Colliery, Warora, C.P., India.
Foster, Thomas, Oaks Colliery House, near Barnsley.
Foulstone, H., Borough Foundry, Barnsley.

Gordon, C. S., 24, Louisa Terrace, Stanley, R.S.O., *via* Chester-le-Street.

Gould, H. D., Birley Collieries, Sheffield.
Gray, W. J., Craig Villas, Woodhouses, Sheffield.
Greene, **John**, Prior's Lee, Shifnal, Shropshire.
Guest, **James**, Chester Road, Brownhills, Walsall.

Hadley, **William**, Birchenwood Colliery Company, Limited, Kidsgrove, Stoke-upon-Trent.
Hall, **George**, Broomhall Villa, Broomhall Park, Whittington, Chesterfield.
Halliwell, J. W., Hucknall Torkard, Notts.
Hampson, **Alexander**, St. Helen's Colliery, Bishop Auckland.
Handyside, **William**, Jun., 4, Brandling Terrace, Felling-upon-Tyne.
Hare, **George**, Seghill Colliery, Northumberland.
Harle, R. A., Wallsend Colliery, Wallsend-upon-Tyne.
Harrison, **George**, High Park Colliery, Greasley, Nottingham.
Heath, A. S., Adderley Green Collieries, Stoke-upon-Trent.
Heath, **Daniel**, Bell Hotel, Market Drayton, Shropshire.
Hedley, A. M , Medomsley, R.S.O., Co. Durham.
Henderson, **William**, Wheatley Hill Colliery, *via* Trimdon Grange.
Henry, **James**, Howgill Staith, Whitehaven.
Henshaw, **John**, Butterley Park, Butterley, Derby.
Herron, **Edward**, 4, Holly Terrace, Stanley, R.S.O.
Heslington, **Alfred**, Danesmoor, Clay Cross, Chesterfield.
Heslop, **William**, Hunwick, Willington, Durham.
Hewitt, **Joseph**, Heron Cross, Fenton, Stoke-upon-Trent.
Hill, **Robert**, Norton Colliery, Smallthorne, Burslem, Staffordshire.
Hill, **William**, Manor Street Foundry, Fenton, Stoke-upon-Trent.
Hindmarch, **John**, Isabella Pit, Newsham, Blyth.
Hobson, **John**, Crigglestone, Wakefield.
Hobson, **Moses**, Shildon, *via* Darlington.
Hornsby, **Demster**, Herrington Pit, New Herrington, Fence Houses.
Howe, **James**, Jun., East Cross Street, Langley Park, Durham.
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Hughes, **James Nicholson**, Hedley Hill Colliery, Waterhouses, Co. Durham.
Hulett, **Charles** T., Lilleshall Collieries, St. Georges, Wellington, Salop.
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Hunter, **Christopher**, Cowpen Colliery Office, Blyth, Northumberland.

James, A. A., Croxdale, near Durham.
Jenkins, J. P., Town Hall, Penryn.
Jepson, W. W., Mexboro' House, Selston, Alfreton.
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Johnson, **William**, Framwellgate Moor, Durham.
Joyner, **Henry**, Snydale Lane, Cudworth, near Barnsley.

Kellett, **Robert**, Copley Lane, Butterknowle, R.S.O., Co. Durham.
Kenyon, G. C., Nostell Colliery, Wakefield.
King, **Fred**, 1, Shankhouse Row, Shankhouse, near Cramlington, Northumberland.
Kirk, **Samuel**, Colliery Yard, Cinderhill, Nottingham.
Knight, **John** L., Adderley Green Collieries, Stoke-upon-Trent.

Lambert, R. W., 74, Summer Street, Sheffield.
Lawton, **Thomas** A., Wacn and Nerquis Collieries, Chester Street, Mold, North Wales.
Lee, **John**, Whitfield Collieries, Norton-in-the-Moors, Stoke-upon-Trent.
Lightley, **John**, Front Street, Sherburn Colliery, Durham.
Linday, **Robert**, 3, Sebastopol Terrace, Seaham Harbour.
Lindsay, **Thomas**, Cannock Wood Mine, Hednesford, Staffordshire.
Lishman, T. A., Harton Colliery, Tyne Dock, South Shields.
Lockett, **William**, West View, Park Road, Burslem, Staffordshire.
Longdon, **Albert**, Newthorpe, Notts.
Longstaff, **Thomas**, Pool View, Hednesford, Staffordshire.

McGowan, **John**, Jun., 10, Wooland Road, Rock Ferry, Cheshire.
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Marshall, John, 124, Manchester Road E., Little Hulton, near Bolton, Lancashire.
Marshall, J. W., Seddonville, *via* Westport, New Zealand.
Mason, Benjamin, Burnopfield Colliery, Burnopfield, R.S.O., Durham.
Mawson, Thomas T., Pemberton Colliery, near Wigan.
Meakin, A. H., Plumtree Cottage, Queen Street, Eastwood, Notts.
Milburn, William, Cornsay House, Cornsay, Durham.
Miller, Alexander, Niddrie Cottages, Portobello, N.B.
Miller, J. H., South Hetton, Sunderland.
Millership, J. H., Watnall Colliery, Watnall, Notts.
Minnikin, John, Ivy Cottages, Hoyland Common, Barnsley.
Minto, George W., 2, Chapel Row, Ouston, Chester-le-Street.
Morland, Thomas, 24, Langley Street, Langley Park, Durham.
Moulton, Levi, The Villas, Silverdale, Staffordshire.
Mullins, William, 168, Queen's Walk, Meadows, Nottingham.

Naisbit, John, 48, Tudhoe Colliery, Spennymoor.
Naylor, A., Cotes Park Colliery, near Alfreton.
Nixon, John, Florence Coal and Iron Company, Longton, Staffordshire.
Nuttall, G. H., Highfield House, Tinsley Park, Sheffield.

Ord, Samuel, Scott's Terrace, Langwith, near Mansfield.
Owen, W. R., 32, Duke Street, Millom, Cumberland.

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Patrick, J. A., West Pool Villas, Saltergate, Chesterfield.
Peasegood, W. G., Leycett, Newcastle, Staffordshire.
Pedelty, Simon, Clara Vale, Ryton-upon-Tyne.
Percy, R. F., 76, Belvoir Crescent, Sneinton, Nottingham.
Pratt, G. Ross, Springwell Colliery, Gateshead-upon-Tyne.
Proctor, Thomas, Woodhorn Colliery, Morpeth.

Ramsay, John, Tursdale Colliery, Ferryhill.
Ramsay, J. G., Page Bank Colliery, *via* Spennymoor, Co. Durham.
Ramsden, E., Crigglestone, Wakefield.
Rawson, George, Tibshelf, Alfreton.
Rees, J. H., Berry Hill Collieries, Stoke-upon-Trent.
Rhodes, J. H., Upper Pleasley, Mansfield.
Richardson, William, Pleasley Colliery, Mansfield.
Ridley, G. D., Tudhoe Colliery, Spennymoor.
Rivers, John, Bow Street, Thornley Colliery, Durham.
Robinson, George Herbert, Jubilee Chambers, Station Road, Tunstall, Stoke-upon-Trent.
Robinson, William, Calder Grove, Wakefield.
Robson, R., Mirfield Coal Company, Ravensthorpe, near Dewsbury.
Robson, William, Jun., Byers Green Collieries, Bishop Auckland.
Rochester, William, Emma Colliery, Ryton-upon-Tyne.
Roebuck, Walter, Talk-o'-th'-Hill Colliery, Talke, Stoke-upon-Trent.

Saner, Charles B., Rietfontein A, Limited, per Private Bag, Johannesburg, Transvaal.
Severs, William, Beamish View, *via* Chester-le-Street.
Shaw, Charles, Jun., Woodland View, Froghall, Stoke-upon-Trent.
Shaw, Edgar H., Adderley Green Collieries, Stoke-upon-Trent.
Shenton, John, Silverdale, Staffordshire.
Shore, Thomas, Markham Colliery, Duckmanton, Chesterfield.
Shufflebotham, Daniel, Biddulph Valley Collieries, Stoke-upon-Trent.
Simpson, Nelson Ashbridge, Bradley Hall, Wylam-upon-Tyne.
Soar, Charles R., Granville Colliery, Swadlincote, Burton-upon-Trent.
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Stokoe, James, Ravensworth Colliery, Low Fell, Gateshead-upon-Tyne.

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Tarbuck, Harold, Ryhope Colliery, near Sunderland.
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Wardle, Richard, Dunsil House, Fackley, Mansfield.
Watkin, R., Cortonwood Collieries, West Melton, near Rotherham.
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Whitehurst, Henry, Grange Colliery, Burslem, Staffordshire.
Wilbraham, Aaron, Birchwood House, Alfreton.
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Wilson, R. G., Pelton Colliery, Chester-le-Street.

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Stud.Inst.M.E.

* Deceased.

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Allsebrook, G. C., Wollaton, Nottingham.
Archer, M. W., High Priestfield, Lintz Green, Co. Durham.
Armstrong, William, Jun., Cramlington Collieries, Northumberland.

Bannatyne, Claude, 21, Circus, Bath.
Bayldon, Harold Cresswell, The Selukwe Gold Mining Company, Limited, Selukwe, Bulawayo, Rhodesia, South Africa.
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TRANSACTIONS
OF
THE INSTITUTION
OF
MINING ENGINEERS.

THE INSTITUTION OF MINING ENGINEERS.

GENERAL MEETING,
HELD IN THE LARGE HALL AT THE HEADQUARTERS OF THE FIRST SHROPSHIRE AND STAFFORDSHIRE ARTILLERY VOLUNTEERS, SHELTON, STOKE-UPON-TRENT, FEBRUARY 22ND, 1899.

MR. J. A. LONGDEN, PRESIDENT, IN THE CHAIR.

Mr. J. C. **CADMAN**, in formally welcoming the members of The Institution of Mining Engineers to North Staffordshire, said that the North Staffordshire Institute of Mining and Mechanical Engineers had great pleasure in receiving them, and they would be glad to show the members what was worth seeing.

The **PRESIDENT** (Mr. J. A. Longden) said that the members were obliged for the kindness of the local Institute in receiving them. Excellent arrangements had been made for the meeting, and he had no doubt that after the termination of the meeting the members would feel that the North Staffordshire Institute of Mining and Mechanical Engineers had entertained them in a highly satisfactory manner.

Mr. **BENNETT H. BROUGH** read the following "Historical Sketch of the First Institution of Mining Engineers":—

HISTORICAL SKETCH OF THE FIRST INSTITUTION OF MINING ENGINEERS.

By BENNETT H. BROUGH.

The first volume of the *Transactions* of The Institution of Mining Engineers was published in 1889; and it may be of interest to the members to learn that exactly a hundred years before that date, there was published by Mr. Georg Joachim Goeschen, at Leipzig, the first volume of the Transactions of a society with similiar aims. This original idea of forming a federated institution to include mining engineers from all parts of the world was due to the distinguished Austrian mining engineer and metallurgist, Ignaz von Born.

During the last 10 years of the reign of the Empress Maria Theresa, great attention was paid in Austria to the study of mining and mineralogy. In her wise solicitude for the welfare of her country, the Empress fully appreciated the importance of the mining industry. In 1762, she founded a professorship of mining at the University of Prague. The first to occupy the chair was Prof. J. T. A. Peitner von Lichtenfels; and the professorship thus instituted, subsequently suggested the idea of founding the Schools of Mines at Schemnitz in Hungary in 1764, at Freiberg in Saxony in 1765, and at Clausthal in the Harz in 1775.

The most energetic mining engineer of the time was the genial and learned Ignaz von Born, whose name will ever be remembered in the annals of Austrian mining engineering. In 1770, at the age of 28, in conjunction with Count Franz Josef Kinsky and the most eminent scholars of Prague, he founded a society for the study of natural history, which published several volumes of Transactions. Von Born was an enthusiastic Freemason, and most of the members of the society appear to have belonged to that order. Subsequently, he founded, on March 16th, 1780, at Vienna, a masonic lodge composed exclusively of men of letters. Of this lodge, he was the Worshipful Master; and among the members were the composers Haydn and Mozart. The lodge was a sort of learned society, before which numerous important papers were read.

With the experience thus gained he was induced to found the Mining Society (*Societät der Bergbaukunde*), the prototype of the Mining Institutions of the present day. The idea of founding this society originated in 1783 when a number of mining engineers assembled near Schemnitz in Hungary to witness a trial of the Born amalgamation-process for extracting gold from its ores. Among those present were F. W. H. von Trebra, of Zellerfeld, Vice-Captain of His Britannic Majesty's Mines in the Harz, the Prussian Oberbergrath Johann Jacob Ferber, the Saxon Bergrath von Charpentier, John Hawkins from England, Olaus Henkel from Kongsberg in Norway, Fausto d'Elhuyar, the director of the Mexican mines, the Abbé Nikolaus Poda from Vienna, and Anton von Ruprecht from Schemnitz.

The object of the Mining Society was to afford a means of communication between mining engineers of all nationalities, on matters bearing upon the mining industry. Mining engineers from all parts of Europe, and even from Mexico and South America, were enrolled as members. Only two volumes of Transactions were published ; and, owing probably to the death of von Born, which occurred at the age of 48, at Vienna, on July 24th, 1791, and to financial difficulties, the Society soon came to an end.

The circular letter, dated September, 1786, inviting experts to join the society, was to the following effect : —

> The great advantages of mining have long been recognized, for it is the first source of riches. Pure science, too, has begun to get rid of its prejudices against it ; and among men of light and leading there are many that have very successfully pursued it in a systematic manner. But in most cases, the work is carried out in a haphazard fashion ; advantage is taken of the accumulated experience of one man only ; the advice of others working in the same field is dispensed with ; and no information is communicated to others. In this way, the advancement of useful knowledge is hindered, and the misuse of secrets as a cloak to ignorance, and, indeed, often to rascality, is invariably facilitated. These drawbacks were appreciated by the undersigned mining engineers when the recently re-discovered great advantages of amalgamation afforded them a happy opportunity of meeting together in Hungary at Glashütte (or Szkleno as it is called in the Slavonic language) near Schemnitz. They considered that they could best remedy the evils referred to by endeavouring to bring together their own friends and the friends and patrons of mining into one corporate whole, a mining society. They were convinced that in this way the requisite useful knowledge could best be brought into speedy circulation, secretmongery in the service of ignorance and rascality would be checked, and every advantage known to any member, or to all, could be best utilized by the formation of such a society. They drew up a constitution for the society, and they now submit it to the prospective members.

The document is signed by Ignaz von Born, and the 8 other mining engineers present, whose names have been given.

The following is the substance of the statutes appended :—

I. Subjects.—1. Physical geography; 2. mineralogy; 3. mining and machine construction, ore-dressing; 4. mine-surveying; 5. history of mining; and 6. metallurgy.

II. Qualifications.—1. Members must be men of scientific attainments and practical miners and metallurgists. 2. Associates may be theorists studying the sciences enumerated for the practical advancement of mining. 3. Honorary members may be amateurs and patrons of mining.

III. Objects.—To collect all that serves for the advancement of mining in its widest sense, and to communicate it to all the members, to enable them to utilize it in their districts for the benefit of mankind and of the state in which it is applicable. The advantages are obvious, inasmuch as so many manipulations customary in various mines are the so-called secrets, either of individual mortal men or of trade guilds. It may here be pointed out that political or financial secrets are not included.

IV. Obligation of the Members.—1. To communicate to the Society anything bearing upon its work, each from his own district; 2. to state with accuracy nothing but absolute facts and observations; 3. to record failures as well as successes; 4. to test or consider the proposals brought before the Society; and 5. to pay annually at Easter two ducats* to the Treasurer.

V. Obligation of the Society.—1. To make public every useful communication; 2. to communicate to each member the information, drawings, models, specimens or other matters coming within the scope of the Society; and 3. to supply replies to queries on mining subjects from mine-owners or mining departments, for a small fee to be paid to the Society's funds.

VI. Officers of the Society.—The bureau of the Society is not confined to a definite place. For the present, all communications to the Society should be sent to Zellerfeld in the Harz, where the archives of the Society will be deposited and its business transacted.

VII. Council.—The Council must be composed of members of the first class, except in the case of representatives of countries in which educated practical miners are absolutely lacking. The present Council is comprised of—

1. His Excellency the Minister von Heynitz (Prussia); 2. Privy-Councillor von Born (Austria); 3. Mining-Councillor von Charpentier (Saxony); 4. Vice Mine-Captain von Trebra, Secretary and Treasurer (the Harz); 5. His Excellency the Count von Bjelke (Sweden); 6. Prof. Brünnich (Denmark); 7. Mr. Arduini (Italy); 8. Baron de Dietrich (France); 9. Mr. John Hawkins (England); 10. Mr. O. Henkel (Norway); 11. Mr. Angulo (Spain); 12. Mr. d'Elhuyar, senior (Santa Fé); 13. Mr. d'Elhuyar, junior (Mexico); and 14. Privy-Councillor Pallas (Russia).

VIII. Duties of the Council.—1. To propose members; 2. to see that the objects of the Society are carried out in their districts; 3. to obtain from expert members in their districts replies to queries sent them; 4. in the event of the death of a member of council to elect a new one; and 5. to decide by a majority of votes where the archives shall be kept.

IX. Rules.—1. Members who for a year have neglected to fulfil the obligation set forth under Par. IV. shall be struck off the list of members. 2. Replies must be sent to all official communications from the Treasurer and Secretary. 3. Members may publish their names or not, as they please, in communications to the

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* A ducat is worth 9s. 5d.

Transactions. 4. Papers shall be printed in the German language; they may, however, be written in Latin, French, English, Italian or German. 5. Replies to queries shall always be written in German. 6. The scheme thus laid down shall be tried for one year, during which period members may submit to the Council proposals for improvements which shall receive attention.

The invitation sent by the band of pioneers at Schemnitz to the leading mining engineers in all parts of the world was well received, and the published list of members comprised 154 names, distributed as follows:—

Localities.	Members.	Associates.	Hon. Members.
1. Prussia	4	3	—
2. Austria	19	5	3
3. Saxony	11	4	2
4. The Harz	12	16	4
5. Switzerland	2	3	1
6. Sweden	8	2	—
7. Denmark	2	1	1
8. Italy	2	3	1
9. France	7	2	2
10. Great Britain	1	9	1
11. Norway	6	3	—
12. Spain	2	2	2
13. Santa Fé	2	—	—
14. Mexico	1	—	—
15. Russia	2	2	1
Totals	81	55	18

The names of the British members are given as follows:—Mr. John Hawkins (London), Member of Council; Mr. Samuel Vaughan, junior (then in Philadelphia); Mr. Peter Woulff (then in Paris); Mr. Raspe (Cornwall); Mr. Richard Kirwan (Dublin); Dr. Withering (Birmingham); Mr. Tennant (a chemist in Yorkshire); Dr. Hume Edinburgh; Mr. Boulton (Birmingham); Mr. Watt (Birmingham); and the Hon. Charles Greville (London), honorary member.

The Mr. Watt mentioned in this list is James Watt, the great engineer and inventor of the modern steam-engine, who was born in 1736 and died in 1819. The Mining Society was founded seventeen years after he had taken out his patent for the separate condenser. In his biography, by his kinsman Mr. James Patrick Muirhead (London, 1858), there is no mention of his having joined the Mining Society. It is recorded, however, that he learned German in order to peruse Prof. Leupold's *Theatrum Machinarum*, and that during his visit to Paris in 1786 at the invitation of the French government, he made the acquaintance of Prof. Hassenfratz, who may have advised him to join. It is also recorded that in 1779, two Prussian engineers were cordially received by James Watt, and with the information that they obtained the first modern steam-engine in Prussia was built at the instance of Frederick the Great and of his minister, Baron von Heinitz (who was a member of council of the Mining Society), and started on August 23rd, 1785, at a copper-mine at Mansfeld. Mr. Watt's partner, Mr. Matthew Boulton, proprietor of the successful plate manufactory and mint at Soho, near Birmingham, which has been well described as being at that period "a region of rare talents," was a member, as also was his friend and neighbour, Dr. William Withering, the celebrated botanist, who translated Torbern Bergman's *Outlines of Mineralogy* in 1783. Dr. Withering was a Shropshire man, born at Wellington in 1741. Having obtained his degree of Doctor of Medicine at Edinburgh in 1766, he practised at Birmingham, and is best known by his description of barium carbonate, termed by him in 1784 *terra ponderosa aerita*, and named "Witherite" in his honour by Dr. Werner (1750–1817). Mr. Richard Kirwan, who wrote the first systematic treatise on mineralogy in English in 1784, was also a member. He corresponded frequently with Mr. James Watt, and in his letter of December 13th, 1783, gave positive assurance that Prof. Lavoisier had heard of Mr. Watt's theory of the composition of water, prior to the publication of his own memoir on the subject. Mr. Kirwan was born in 1733, elected a Fellow of the Royal Society in 1780, and received the Copley medal in 1782. He was a very picturesque character. The younger son of a West of Ireland family, he entered the Jesuit noviciate, but gave it up within a year. When his brother was killed in a duel, he succeeded to the family property, and took to science. He lived in London for 10 years and subsequently in Dublin. He was very quaint in his manners, always receiving his friends stretched at length on a sofa before the fire. To protect himself from cold he always wore a slouched hat, even at viceregal levees. He kept a pet eagle and six large dogs, and lived upon a diet of ham and milk. The Hon. Charles Greville (1749-1809), another of the British members, was also a friend of Mr. Watt. He it was who succeeded in getting James Watt's name removed from the list of gentlemen nominated for the burdensome honour of sheriff.

Mr. Rudolph Eric Raspe, another of the members, was the author of numerous scientific works, including an account of some German volcanoes in 1776; he translated the works of Ignaz von Born and J. J. Ferber. Born in 1737, he was educated at Göttingen, and became curator of the collection of coins at Cassel, where he appropriated 2,000 dollars' worth of medals. He was hunted over Germany, being captured at Clausthal, whence he escaped to England, and was for some years storekeeper and assayer at Dolcoath mine in Cornwall. There he wrote

Baron Munchausen. Subsequently he was mixed up with some unsatisfactory prospecting in Scotland, and victimized a Highland proprietor. The incident furnished the material for Sir Walter Scott's Dousterswivel in *The Antiquary*. He died in 1794, having sought refuge in the North of Ireland.

Mr. Tennant was a Yorkshire chemist. He was elected a Fellow of the Royal Society in 1785, and received the Copley medal in 1804. He published the results of many researches, notably upon metals of the platinum group, having discovered the metals osmium and iridium. He was appointed professor of chemistry at Cambridge in 1813, but only delivered one course of lectures, as he was killed by a fall from his horse on February 22nd, 1815, when riding out with Baron von Bülow to the column of the Grande Armée at Boulogne. Mr. Peter Woulff was also an English chemist and Fellow of the Royal Society, who died in 1806. He invented the three-necked bottle largely used in laboratory practice, bearing his name. Mr. John Hawkins (1758-1821) was another Fellow of the Royal Society. He wrote on the geology of Cornwall, and was a *dilettante* collector of all kinds of things. The Dr. Hume mentioned in the list was probably Sir A. Hume, Bart. (1743-1838), who was a great mineral collector. He was elected a Fellow of the Royal Society in 1775 and was senior Fellow at his death. He was one of the founders of the Geological Society of London, and served as its Vice-President from 1808 to 1813.*

Among the members enumerated in other countries there are many famous names. Of these, the following may be mentioned :—Sir William Hamilton (1730–1803), the British Ambassador at the court of Naples from 1764 to 1800, who took an active part in the excavation of Pompeii and formed a rare collection of antiquities, which was afterwards purchased for the British Museum. He was the husband of Lord Nelson's Emma, Romney's "divine lady," and uncle of the Hon. Charles Greville referred to above, his predecessor in the affections of that notorious lady. Prof. Johann Jacob Ferber was the leading mineralogist, geologist and metallurgist of his time. Born in 1743, in Sweden, he spent a large portion of his life in scientific travels, which he described in various treatises written in German. In 1781, he was professor in St. Petersburg, and in 1786 he was called to Berlin to fill the post of *Oberbergrath*. He died in 1790, when travelling in Switzerland. To him, Ignaz von Born addressed the letters describing his

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* The writer is indebted to Mr. H. Bauerman for much valuable help in the search for biographical details of the English members.

Hungarian travels in 1770. Prof. Klaproth, of Berlin, the chemist, who in 1792 discovered the element titanium, was a member, as also were: Mr. Carl Haidinger, the geologist of Schemnitz in Hungary; Count von Wrbna, of Vienna, who, by introducing casting in sand and by converting his ironworks at Horzowitz into a model establishment, inaugurated a new era in foundry-practice in Austria; Mr. J. F. Lempe, of Freiberg in Saxony, the editor of the first German mining journal, published from 1785 to 1799; J. W. Goethe (1749-1832), the most celebrated of German poets, then privy councillor at Weimar, with charge of the mines of the Duchy; he was deeply interested in geology and mineralogy, and even when relieved from the most irksome of his public duties, continued to take an interest in the Ilmenau mines; Prof. de Saussure, of Geneva, the Swiss geologist, who was the first to make the ascent of Mont Blanc; Mr. Sven Rinman (1720-1792), of Eskilstuna, the great Swedish ironmaster, who, in his monumental treatise published in 1782, was the first to combine theory with practice in the metallurgy of iron; Mr. Polhammer of Falun, the son of the great Swedish mechanical genius; the Duke de La Rochefoucauld, the author of a book of travels through the United States in 1795; Baron L. de Malesherbes, the minister of Louis XVI. who defended the king before the Convention, and was guillotined in 1794; Lavoisier, the illustrious French chemist, the creator of modern chemistry, who, simultaneously with Dr. Priestley in England and Scheele in Sweden, discovered oxygen, he also was guillotined in 1794; Baron de Dietrich, member of an old family of ironmasters in Alsace, who was commissioned by the French government in 1785 to report on the mines and works of Alsace, Lorraine and the Pyrenees, he published only three volumes of his work, for he, too, fell a victim to the guillotine on December 29th, 1792; Prof. de Morveau, who applied Lavoisier's chemistry to the study of iron, and on the foundation of the *École Polytechnique* in 1794 became professor of chemistry; Prof. Hassenfratz, the author of a treatise on the metallurgy of iron, who was appointed professor of metallurgy at the School of Mines founded by the Republic in Paris, and organized the manufacture of cannon when the Republic became involved in war with the monarchical states of Europe; and Mr. Peter Simon Pallas, the illustrious explorer of Siberia and the discoverer of the meteoric iron that now bears his name.

The Secretary and Treasurer of the society, Mr. F. W. H. von Trebra, was the first matriculated student at the Freiberg School of Mines. He was author of a wellknown geological work *Erfahrungen vom*

Innern der Gebirge (Dessau, 1785), in which he ascribed the origin of mineral veins to the action of "putrefaction and fermentation." He was the most energetic mining official in the Harz mining-district, which, at that period was, in the words of the translator of a work on *The Natural History of Hartz Forest in His Majesty King George's German Dominion* (London, 1730),

> Counted to be the richest Spot of Ground in all Germany; for here are more than one hundred and ten Capital Mines, several of which have small ones belonging to them; some are work'd for the King of Great Britain (as Elector of Hannover) on his own Account, and the rest farm'd out. The mines of Wildman, Clausthal, Zellerfeld, Lautenthal, St. Andreasberg, etc., are Silver ones, and some of them so rich that Nine hundred thousand Rixdollars have been coined in one year from that of Clausthal only.

In 1801, he was appointed *Oberberghauptmann* at Freiberg, and died on June 16th, 1819.

Ignaz von Born, the founder of the society, was born on December 26th, 1742, at Carlsburg in Transylvania. In 1759, he became a Jesuit, but in 16 months he withdrew from the order. After studying law at Prague, he spent some years in travel, and returned to Bohemia, where he devoted himself, under the guidance of Prof. J. T. Peithner von Lichtenfels, to the study of natural history. In 1770, he received an appointment in the mining department of Prague, and the same year undertook an educational journey to the Banat, Transylvania and Hungary, communicating the mineralogical results of his observations to his friend, the celebrated mineralogist, Prof. Ferber, who found them of sufficient interest to merit publishing in 1774. They were translated into English by Mr. Raspe in 1777, and into French in 1780. On this journey, Ignaz von Born met with an accident at Felsöbánya which undoubtedly eventually shortened his life. He describes the accident (which is very similar to the terrible disaster that occurred on May 10th, 1897, at the Snaefell Mine in the Isle of Man) in a letter to Prof. Ferber, dated August 22nd, 1770, in the following manner:—

> My long silence is the consequence of an unhappy accident which was very near putting an end to my life. To examine the method of fire-setting employed at Felsöbanya, and the great effects produced by so small an expense of wood, I visited the great mine when the fire was hardly burnt down, and when the mine was still filled with smoke. An accident made me tarry somewhat longer in the shaft by which the smoke went off. In short, I lost my senses, and 15 hours after I was restored to myself by blisters and other applications. My lips were swollen, my eyes ran with blood, and all my limbs lamed. Without the assistance of a skilful young physician at Nagybanya, and of the Administrative-Inspector von Gerham, you would undoubtedly have been deprived of your friend. The question is still

> whether he is to be saved, for a violent cough and acute pains in the loins, which alternately put me on the rack, are quite sufficient to destroy this thinly framed machine. If that should be the case, procure me the honour that my name at least is inserted in the martyrology of naturalists.

Prof. Ferber made a similar journey through Italy, and wrote letters on mineralogy to Ignaz von Born, who published them in 1773. By this time the latter was a member of the Academy of Sciences of Stockholm, of the Academy of Siena, and of the Learned Society of Padua. In 1774, he was elected a Fellow of the Royal Society of London. In 1776, he was summoned from Bohemia by the Empress Maria Theresa to take charge of the Imperial collection of minerals. In 1779, the Empress conferred upon him the title of *Hofrath.* Having successfully conducted experimental research on amalgamation in Vienna, he obtained permission from the Emperor Joseph II. to test the method on a large scale at Schemnitz, where gold and silver-ores were mined. The report of these trials soon spread over Europe, and gave rise to the first international mining congress, which took place, as has already been stated, near Schemnitz in 1783, under the presidency of Ignaz von Born. His method was fully described in a treatise published by him in 1786. It was translated into French in 1788, and into English by Mr. Raspe in 1791, the year in which the author died. His services in introducing amalgamation into Austria were rewarded by the Emperor by the grant of one-third of the amount saved by its adoption during 10 years. The success of the invention was celebrated at Ignaz von Born's Masonic Lodge by a banquet given to him on April 24th, 1785, for which occasion a cantata was specially composed by Mozart. By his activity as a mineralogist, miner and metallurgist, by the high position which he held among the men of science of his day, and by his numerous published works, Ignaz von Born acquired a world-wide reputation and a great influence over his contemporaries, and by the introduction of the amalgamation of ores he earned lasting fame in the annals of Austrian mining.

Space will not permit of reference being made to many of the other notable members. The brief biographical details given may, however, suffice to show that the Mining Society included the most brilliant investigators of the period.

Financially, its success was not so brilliant. The statement of accounts of the society from May, 1787, to March 9th, 1789, shows that the expenditure was as follows:—

	Rthlr.	Gr.	Pf.
I.—Postage—			
Of letters and parcels received	15	3	4
Of letters despatched	5	0	0
II.—Printing—			
Circulars	8	22	0
Reprints of memoirs	1	14	0
Paper, printing and illustrations of vol. i. of Transactions...	371	19	0
Total	402	10	4

The income was as follows :—

	Rthlr.	Gr.	Pf.
Subscriptions	366	16	0
Balance due to Treasurer	35	18	4
Total	402	10	4

The second statement from March 10th, 1789, to May 15th, 1790, shows that the expenditure was as follows :—

	Rthlr.	Gr.	Pf.
Balance due to Treasurer	35	18	4
I.—Postage—			
Letters and parcels received...	12	10	7
Letters despatched	7	0	0
Linen, string, etc., for packing	1	15	4
II.—Disbursed by Council outside Germany ...	12	8	0
III.—Further cost of vol. i. of Transactions ...	208	19	5
IV.—Cost of vol. ii. of Transactions...	363	4	0
Total	641	3	8

The income was as follows :—

	Rthlr.	Gr.	Pf.
Further subscriptions to date	425	0	0
Balance due to Treasurer	216	3	8
Total	641	3	8

A reichsthaler (rixdollar) was equal to 4s. 6d.; 12 pfennige were equal to 1 groschen; and 24 groschen were equal to 1 reichsthaler.

Thus, for the 3 years the total income was 791 rthlr. 16 gr., and the expenditure 1,007 rthlr. 19 gr. 8 pf.

Of the Transactions, two volumes only were published. Copies of these are preserved in the Libraries of the Museum of Practical Geology, London, and of the Schools of Mines at Freiberg, Clausthal and Berlin.

The first volume, issued in 1789, covers 408 pages, and is illustrated by 6 folding-plates. The contents comprise eleven memoirs dealing with the following subjects :—

1. "The Vöröspatak Gold-mines in Transylvania," by Mr. von Müller, of Salatna.
2. "A Fossil from the Harz," by Prof. Gmelin, of Göttingen.
3. "The Ochre of Berry in France," by Baron de Dietrich, Commissaire du Roi à la visite des mines.
4. "The Water-conduits of the Harz, with Special Reference to the two most Important Mines Dorothea and Carolina at Clausthal," by Mr. G. A. Stelzner, of Clausthal, dated February 7th, 1788.
5. "Observations of Magnetic Declination in the Harz," by Mr. F. W. H. von Trebra and others.

6. "The Condition of the Mines in Carinthia in the Sixteenth Century," by Mr. Carl von Ployer, of Innsbrück, Tyrol.

7. "Ancient Gold-mines at Steinheide, in Thuringia," by Mr. C. G. Voigt, of Weimar.

8. "The Quicksilver-mines of Horzowitz, in Bohemia," by Mr. Rosenbaum.

9. "Tyrolean Silver and Copper-smelting Processes," by Mr. I. von Born.

10. "The Theory of Amalgamation," by Mr. Fausto d'Elhuyar, Director-general of the Royal Spanish Tribunal of the Mining Corps in New Spain.

11. "Recent Progress in Amalgamation," by Mr. F. W. H. von Trebra, His Britannic Majesty's vice-mine-captain in the Harz.

The second section of the volume contains brief communications and abstracts.

The second volume of the Transactions, issued in 1790, covers 468 pages, and is illustrated by 5 folding-plates. The contents comprise eight memoirs dealing with the following subjects :—

1. "The Gold-mines of La Gardette," by Mr. I. G. Schreiber, Directeur des mines de Monsieur et Inspecteur honoraire des Mines de France, dated January 15th, 1788.

2. "A Chemical Examination of Crystals from St. Andreasberg, Harz, and on a Variety of Heavy-spar from the Rammelsberg," by Mr. Westrumb, apothecary at Hameln.

3. "A new form of Mine-waggon," by Mr. Stockicht, of Braubach.

4. "The Dressing of Ores at the St. Anna mine, Kremnitz, Hungary," by Mr. I. F. W. von Charpentier, of Freiberg.

5. "The Smelting of Lead-ores in Reverberatory Furnaces," by Mr. Ignaz von Born.

6. "The Use of Desulphurized Coal (Coke) for Smelting Argentiferous Lead and Copper Ores at the Weyer Works," by Mr. Kleinschmidt, of Ofenbach. This paper, dated September, 1789, give the results obtained with coke, the use of which was suggested by Mr. Jars, who had seen it employed in England.

7. "The History of Amalgamation at Joachimsthal, Bohemia," by Mr. Carl Anton Rössler. This paper, dated March 28th, 1789, described the results obtained with the Born process in Bohemia.

8. "The Theory of Amalgamation," by Mr. Fausto d'Elhuyar.

The second section of the volume contains brief communications and abstracts. Amongst others, there is a letter from Mr. John Hawkins, dated London. June 28th, 1789, in which he reports that the celebrated copper-mines of Anglesey were as productive as ever, and in consequence the price of copper had become so reduced that many of the Cornish mines had been shut down. Tin-mining was more prosperous, the sales during the previous year having been the best on record.

The most recent communication in the volume is from Mr. Carl Haidinger, and is dated May 20th, 1790.

Five hundred copies of each of the two volumes of Transactions were printed. No further volume was published, and the writer has been unable to find any notice of the dissolution of the society. Apparently, it quietly passed out of existence when the leading spirit, Ignaz von Born, died in 1791. The finances of the society were in a critical condition, and its losses by death were enormous. Prof. Ferber, von Born's most energetic coadjutor, died in 1790, and the leading French members shortly afterwards perished on the scaffold. The times were troublous, and ill suited for peaceful international relations. In April, 1792, France was at war with Austria. When Louis XVI. was beheaded on January 21, 1793, revolts occurred in every part of France. Great Britain, Holland, Spain, Naples and the German States combined together against the Republic. Hanover, in which state the offices of the Mining Society were situated, did not escape the general turmoil; Hanoverian troops taking part in the wars against the French Republic, the expenses of their maintenance being defrayed by Great Britain. Surrounded by political troubles, with its most active members dead and its treasury exhausted, it is easy to see that the Mining Society was compelled to close its doors.

It did excellent work during its brief existence, and the ideas embodied in its constitution were destined to be developed in a remarkable manner. The numerous mining institutes subsequently founded on similar lines, became (to borrow a metaphor from Mr. C. W. Hunt) the "savings-banks of civilization," the repositories and guardians of the results of experiments and experience that would otherwise have been lost to the world.

The **President** remarked that by section IV. of the statutes, in addition to communicating to the society anything bearing upon its work, each member from his own district, and stating with accuracy nothing but facts and observations, they had to record failures as well as successes. There was not the slightest doubt that more was to be learned from failures than from successes; but, unfortunately, members were diffident and did not record their failures. He had much pleasure in proposing a vote of thanks to Mr. Bennett H. Brough for his interesting paper.

Mr. W. N. **Atkinson** (H.M. Inspector of Mines, North Staffordshire), in seconding the vote of thanks to the author of the paper, remarked that a considerable amount of investigation was entailed in searching for the interesting facts which were recorded in it, and the paper should be of value as showing how much good work might be done under great difficulties. He had great pleasure in seconding the vote of thanks.

The vote of thanks was carried with acclamation.

Prof. **Henry Louis** read the following "Further Notes on Pit-props":—

FURTHER NOTES ON PIT-PROPS

By Prof. HENRY LOUIS.

When the author had the honour of submitting his paper on the strength of pit-props nearly a year ago to this Institute,* he was asked by several members for information as to the strength of oak props. Through the kindness of Mr. William Cochrane, the author has now obtained half a dozen ordinary oak props, which he has tested in the same way as the previous ones, with the following results :—

Number of Prop.	Minimum Diameter of Top.	Area of Top.	Length of Prop.	Actual Breaking Weight.	Breaking Weight per Square Inch of Area.	Age of Prop.	Notes.
	Inches.	Sq. In.	Inches.	Tons.	Tons.	Years.	
1	3·3	11·76	40½	8·98	0·76	55	Much bent; buckled at big knot in middle.
2	3·9	12·76	36	13·56	1·06	55	Very bent; buckled in crown of bend.
3	3·05	10·18	43	11·31	1·11	47	Fairly straight; buckled in middle; tough, stringy break.
4	3·55	10·93	43½	9·00	0·83	27	Buckled at knot in middle.
5	3·5	10·64	41	8·37	0·79	50	Twisted stick; buckled at several small knots in middle.
6	3·9	12·57	40⅓	12·29	0·98	56	Upper part much bent; buckled in crown of bend.
6*a*	4·5	16·84	21	21·90	1·30	60	Straightest part sawn off last prop; buckled about middle.

It will be noted that, of the six original props tested, the best result was given by the straightest prop, yet this was only 1·11 tons per square inch, whilst the average of the six was only 0·92 ton per square inch. This figure compares very unfavourably with the result obtained for ordinary Baltic soft-wood props, namely, 1·57 tons, being only 60 per cent. of that figure; the lowest figure obtained for soft-wood, namely, 1·10 tons, is exactly equal to the highest given by an oak prop. It is therefore impossible to doubt that the oak prop is far weaker than an ordinary Baltic prop. At the same time, the considerably higher result given by the shorter straight piece marked 6*a*, which was cut off prop No. 6, shows that the weakness lies not in the material itself, but in the shape and structure of the entire prop; it also indicates with great clearness the fact which these experiments have already brought out, that tests made on small, carefully selected samples of wood give no information whatever as to the strength of the prop as such, which fails as a rule by yielding at some special point of weakness. In tables of the resistance of timbers to crushing, oak is generally given as much stronger than (up to about twice as strong as) whitewood. Yet an oak prop is undoubtedly weaker than a whitewood prop.

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* *Trans. Inst. M.E.*, vol. xv., page 343.

Since the publication of the writer's first paper, a paper has been read on a very similar subject in Germany by Mr. Ch. Dütting, inspector of mines at Saarbrücken, which has been reproduced in full in *Glückauf*.* It is obvious that the author and Mr. Dütting have been working independently on exactly similar lines, and each apparently in complete ignorance of the work that was being done by the other. The entire subject is now being made the subject of an enquiry by a Royal Prussian Commission, while, as usual, our Government leaves such investigations to be carried out—if at all—by individual enterprise. Having regard to its immense importance, a brief review of Mr. Dütting's work and a comparison of his results with those obtained by the author may be of some interest. The experiments were performed by crushing in a hydraulic press sound pit-props as straight and as uniform in size as possible, varying from 3 feet 3 inches to 8 feet 3 inches in length. It was found that normal props broke under an average load of 25 to 28 tons, under which the prop almost invariably gave way by buckling, even when the length was only equal to 10 diameters. The ordinary formulæ for resistance to bending cannot, however, be applied here, because these depend upon the theory of elasticity, and are thus inapplicable when actual breakage sets in. Furthermore, these formulæ only apply to cases in which the length exceeds 15 diameters, which was never the case in any of the props tested. Experiments were tried upon four species of timber, namely, beech, spruce, Scotch fir and oak, which were tested (*a*) immediately after being felled, (*b*) 5 months after felling (the bark being left on), and (*c*) after drying for a week at 65° C., after being barked. The results are shown in the following table :—

	(*a*) Props Tested Immediately after Felling. Tons per Square Inch.	(*b*) Props Tested after Five Months. Tons per Square Inch.	(*c*) Props Tested after Being Dried. Tons per Square Inch.
Beech	1·45 ...	1·59 ...	1·62
Spruce	1·25 ...	1·36 ...	1·51
Scotch fir	1·17 ...	1·21 ...	1·32
Oak	1·10 ...	0·95 ...	1·32

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* "Ueber die Gebrauchsfähigkeit einiger Holzarten zum Grubenausbau." *Glückauf*, 1898, vol. xxxiv., page 797 ; and *Trans. Inst. M.E.*, vol. xvi., page 563.

The results obtained by the author are practically comparable with those in column *b* of Mr. Dütting's results, and are as follows:—

	Tons per Square Inch.
Spruce (Baltic whitewood)	1·57
Scotch fir	1·20
Oak	0·92

These results corroborate each other in so remarkable a degree, that their accuracy may be taken as practically proved beyond dispute, while the increase of strength due to seasoning is shown equally in both sets of tests.

Mr. Dütting has commenced a few tests on the resistance to decay of the same four species of timber; these are being carried out by placing a number of props in the intake and return airways of a mine; in the latter case it has been found that beech props were weakened to the extent of 11·4 per cent., spruce props 2·2 per cent., Scotch fir 4·3 per cent., and oak 23 per cent. These tests seem to show that coniferous wood resists the decaying influences of a return air-current far better than do the woods of deciduous trees. The rapid decay of oak props is the most startling feature of these results; it came as a surprise to the author, and no doubt to most mining engineers who have seen how wonderfully well oak-timbers have resisted decay for—in some cases—even centuries. Further experiments are, however, promised on this subject, hence it may be preferable to withhold comments upon what Mr. Dütting himself states is somewhat of the nature of an interim report. He has further made experiments on the power of the same four woods of giving premonitory indications of yielding, and finds that spruce gives the longest notice, next Scotch fir, then beech, and lastly, oak. His ultimate conclusions are that beech has been undervalued by mining engineers, whilst oak has been overrated. He has also had good results with acacia wood, which are not reproduced here, as being of little interest to British mining engineers.

The author has thought it well to draw attention to the above work as a proof that foreign governments at any rate are aware of the appalling ratio that falls of roof bear to the total of mining casualties, and that they are experimenting in the hop.s of reducing the death-rate due to this cause, whilst he is also gratified at being able to produce so soon independent evidence of the general accuracy of the results which he had already submitted to this Institution.

The **President** (Mr. J. A. Longden) said that those members who had had the pleasure of reading Prof. Louis' first paper would, he felt sure, acknowledge that they were greatly indebted to him for the valuable experiments which he had made respecting the strength of pit-props. When the members realized that a prop 5 inches in diameter could sustain a weight of 30 tons, they would understand what an element of safety a prop really was in a mine.

Mr. J. **Stephen Jeans** (London) said that mining engineers were much indebted to Prof. Louis for his labours in carrying out this very important work, and he could not help thinking that The Institution of Mining Engineers would do well to appoint a committee to assist Prof. Louis in his experiments, which were of supreme importance to the mining industry. He suggested that such a committee should extend their enquiries into the relative suitability of different descriptions of timber for mining purposes, together with the methods of treating timber for use in mines.

Mr. **John Gerrard** (H.M. Inspector of Mines, Manchester) said that the members were indebted to Prof. Louis for continuing his researches into this interesting subject, which had important practical applications. Prof. Louis had brought to their acquaintance and knowledge facts which they did not know before, and he was sure that further useful information might be obtained. Much had been done (and he was sure that it was largely due to the assistance of the Mining Institutes of the country) to reduce the loss of life due to explosions in mines, and they now had before them the very important question of the loss of life due to falls of ground. He was of opinion that the time had arrived when mining engineers should give the same amount of attention to the subject of fatalities from falls of ground as they had in the past devoted to the subject of fatalities from explosions. He felt sure that there would be some tangible result from such an enquiry, and that the loss of life could be materially reduced. He had pleasure in proposing a vote of thanks to Prof. Louis for his valuable paper, and he expressed the hope that he (Prof. Louis) would continue his researches.

Mr. J. C. **Cadman** (Newcastle-under-Lyme), in seconding the vote of thanks, said that the question of timbering was one of the most important questions that mining engineers had to consider at the present day. By an increased strength of prop great safety ensued, and this was of especial importance in the North Staffordshire district, where heavy props were used. The fact that timber, well seasoned, was increased in value over 49 per cent. was an important matter, and one that almost suggested to him whether it would not be worth while for mine-owners to erect "seasoning-houses." Mine-timber was often newly sawn, and full of sap, and if used before being stored caused an increase in the cost of working. It would therefore be desirable to erect seasoning-houses in which the wood should be dried before being used.

Mr. T. **Vaughan Hughes** (Birmingham) agreed with the suggestion as to the seasoning of timber before being used, and argued that it was one that should be generally adopted.

Mr. **Frank R. Simpson** (Blaydon-upon-Tyne) wrote that the results of Prof. Louis' experiments would be valuable to mining engineers as showing the unsuitability of oak for use as pit-props. Whilst fully appreciating the concluding remarks, he would mention that, although the number of deaths due to falls of roof was so large, his experience was, that these accidents were seldom, if ever, due to breaking, but rather to the absence or displacement of timber by side or other pressure. This was no doubt due to the premonitory indication given by the timber, which is a very decided advantage as compared with the use of metal or improperly set steel, of which fracture or displacement might occur with very little warning.

The vote of thanks to Prof. Louis was carried unanimously.

Prof. Henry Louis, (Newcastle-upon-Tyne), in replying to the discussion, said that in the first place he would like to thank the members for the kindly reception which they had given to his paper. He would be very pleased to test any props that might be sent to him which had been seasoned in any way. His experiments were commenced with the idea of looking into the question of falls of ground, but this was a far-reaching and wide subject, and it seemed to him that it was one that could not be taken as a whole; and he had therefore commenced to take it piecemeal. He would heartily welcome the appointment of a committee who could investigate the whole question.

Mr. E. G. **Hiller** read the following paper on "The Working of the Boiler Explosions Acts, 1882 and 1890":—

THE WORKING OF THE BOILER EXPLOSIONS ACTS, 1882 AND 1890.

By E. G. HILLER.

There are two Boiler Explosions Acts: one, the original Act of 1882, and the other that of 1890, which is merely a supplement to the earlier Act, and extends its operations to various additional classes of boilers.

These Acts embody the principle of full investigation of the cause of boiler explosions, the necessity for which had been recognized long before these Acts were passed. So long ago as 1870-71, a Select Committee of the House of Commons enquired into the subject of boiler explosions, and among the principal suggestions of their report was the desirability of complete investigation by someone appointed by the Board of Trade in all cases of explosion of steam-boilers.

Prior to the passing of these Acts, the only investigations of an official character were those conducted in accordance with the instructions of the coroner (where the explosion had caused loss of life), and these varied very greatly in efficiency. If the coroner was fortunate enough to obtain the services of a man who really did understand boiler explosions, a rational account of the cause and origin of the explosion might be ascertained, but in too many cases incompetent persons reported on the explosions, with the result that a very large number of the verdicts were based on incorrect evidence, and were often very misleading and mischievous.

Boiler Explosions Act, 1882.—The principal provisions of the Boiler Explosions Act of 1882 are the following:—That in all cases of boiler explosion notice has to be sent to the Board of Trade, and the Board of Trade then appoint an engineer to make a preliminary enquiry into the explosion, and to take evidence and make such examination and such investigation as he thinks proper.

The Board of Trade may afterwards, if they think proper, order that a formal investigation shall be made into the explosion, this formal investigation being conducted by two commissioners appointed by the Board of Trade, one of these being a lawyer and the other an engineer.

The Court of Formal Investigation has full powers for taking evidence upon oath and requiring the production of papers and the obtaining of any other information or evidence required. The commissioners, after holding the formal investigation, report and they may order the whole or part of the cost of the conduct of the investigation to be paid by the persons who are summoned by them or by the Board of Trade. There is also a small fine which may be imposed where the owners of the exploded boiler fail to give due notice to the Board of Trade.

This original Act did not apply to boilers used for domestic purposes or to boilers in the service of Her Majesty, or to boilers on board of steamships having certificates of the Board of Trade, or into boiler explosions into which enquiry may be held under the provisions of the Coal-mines Regulation Act, 1872, or the Metalliferous-mines Regulation Act, 1872.

Extension of Boiler Explosions Act, 1890.—By the amending Act of 1890, however, the application of the Act was extended so as to cover all boilers other than those on railways or those used in the service of Her Majesty or those used exclusively for domestic purposes.

Definition of Boiler.—In the original Act, the term "boiler" means an enclosed vessel used for generating steam or for heating water, or for heating other liquids, or into which steam is admitted for heating, steaming, boiling, or other similar purposes. This is a very wide definition indeed. It includes not only what is usually understood by the term "steam-boiler," but also vessels through which steam passes, such as steam-pipes, stop-valves, steam-engine cylinders, also all kinds of evaporating vessels, such as tar-cylinders, ammonia-stills, and all that large class of vessels which are used in connexion with steam for various manufacturing operations, such as kiers, straw-boilers, steam-jackets, steam-pans and vessels of that character, and also hot-water circulating boilers.

No Definition of Boiler Explosion.—It is curious that in neither of the Acts is any definition given of a boiler explosion. It is well-known that a large variety of accidents may happen to steam-apparatus without anything of the nature of an actual explosion taking place. Thus, for instance, steam-pipe joints often leak. Sometimes, such leakages result in an outrush of steam which is very alarming in its character to persons who are not used to it. Riveted seams, again, give way from time to time, resulting in serious leakage, but still again without actual explosion taking place. Small places in a boiler may locally waste through, resulting in an escape of steam and water, still without any explosion resulting.

There is, in the Boiler Explosions Acts, no indication or direction as to which of these occurrences are to be considered explosions and which are not. This is one of the features in the Act which leads to a considerable misapprehension as to the meaning of the statistics which are published as to its working. Considerable numbers of minor leakages and minor failures, such as have been before mentioned, take place in large works throughout the country, and no doubt if all these were reported it would appear on the face of it that an immense number of boiler explosions took place each year.

The Board of Trade have no direction in the Act as to what they are to investigate or what they are not to investigate, and as a rule they appear to investigate all cases which are reported to them.

Status of Court of Formal Investigation.—The status of the Court of Formal Investigation is a matter of interest. Although the commissioners have very great powers of finding firms and persons to blame, and also of ordering them to pay costs where they think necessary, there is no right of appeal whatever against the judgment of the court, and when once it is given there it has to rest. Further, the commissioners of any particular enquiry are not necessarily the same as those of any other enquiry which follows. One set of commissioners' judgments therefore might differ very much in similar cases from those of other commissioners. It would not have been surprising, under these circumstances, if a number of discordant and inconsistent judgments had been given in different enquiries.

However, so far as this country is concerned, the Board of Trade generally appear to have adhered to some continuity in the appointment of commissioners by retaining the same gentleman as the lawyer commissioner in most of the cases ; and, as a result, in spite of occasional hardship in judgment, the Court of Formal Investigation would generally appear to have formulated its judgment in various cases on fairly consistent and useful guiding principles to which the writer will refer later.

In the cases of Ireland and Scotland, however, there would not appear to have been the same continuity in the manner in which the court is conducted, and the results of the formal investigations often seem to be very different from what they would have been if those investigations had been conducted in England.

Formal Investigations.—In the course of the administration of the Acts, no formal investigations were held until the year 1889-90, but since that time the custom of the Board of Trade appears to have been to order a formal enquiry into all cases of serious explosion, with the object of giving greater publicity to the investigation and to bring home to steam-users their responsibilities in respect of the boilers which they use. From July 1st, 1890, to June 30th, 1898, in all 186 formal enquiries have been held, and the boiler-owners and others concerned with the steam-boilers which exploded have been ordered to pay a total sum in costs amounting to £4,646.

Total Number of Accidents Investigated under the Acts.—Fig. 1 (Plate I.) has been drawn to show the total number of accidents investigated under the Boiler Explosions Acts both in the shape of preliminary enquiries and formal investigations since the institution of the first Act in 1882-3. The ordinary impression of the public is that all the accidents reported under the Boiler Explosions Acts are boiler explosions, and as a consequence of this the large totals which have been reached in recent years, namely, 104 in 1893-94 and 114 in 1894-95, have caused considerable public alarm, leading some to believe that the conduct of manufacturing operations was becoming more lax, that steam-boilers were becoming more dangerous, and that there was urgent need for some repressive legislation to prevent this growth of accident.

Variety of Accidents included in Board of Trade Statistics of the Working of the Acts.—This impression largely arises from the peculiarity of the Boiler Explosions Acts before mentioned, namely, that while there is an extremely wide definition of the term "boiler" there is no definition at all of the term "explosion." Consequently a large variety of occurrences to steam apparatus varying from slight leakages to serious explosions are regularly investigated, and go to swell the return. In the earlier years of the operation of the Acts, the greater part of the accidents investigated were actual explosions, thus in 1882-83 33 out of 45, and in 1883-84 24 out of 41 were actual explosions of steam-boilers. In later years, however, as the Acts have become better known, it has been customary to report many minor occurrences to the Board of Trade which were not mentioned in earlier years. Consequently, these have been investigated, and their numbers have gone to swell the results, making it appear on the surface that steam-boiler explosions are increasing.

As a matter of fact, notwithstanding the growth of industrial operations involving the use of a much larger number of steam-boilers than in past years, the total number of steam-boiler explosions is decreasing. These are shown in Fig. 1 (Plate I.) by the full line, and it will be seen on that line that the average of the first 4 years shown was 31, and the average of the last 4 years shown was 27·5; and this, too, although the figures in the last 4 years, owing to the extension of the Acts to include steam-ships, include the explosions of boilers on sea-going vessels which the first 4 years did not.

In order that the actual condition of affairs as regards the increase of safety in the working of steam-boilers may be shown, Fig. 2 (Plate I.) has been prepared showing the actual number of explosions of steam-boilers, that is to say, boilers used for generating steam on land, in the United Kingdom from 1866 to the end of 1897. The average number of explosions per annum, and of persons killed per annum in the periods 1866 to 1875 and 1886 to 1895 as shown on that diagram, are as follows:—

	Average Number of Explosions per Annum.	Average Number of Persons Killed per Annum.
Ten years from 1866 to 1875 ...	56·1 ...	63·6
„ „ 1886 to 1895 ...	31·7 ...	18·5

Improvement in Safety of Steam Boilers.—It will be seen from these figures that the number of explosions and the number of persons killed, which is a measure of the severity of the explosions, has been very much diminished, and this although the number of steam-boilers in the country has been greatly increased. The safety of conduct of steam-boilers, therefore, in the operations of this country has been vastly improved within the last 30 years, and this, of course, is only what might have been expected from the improvements which have taken place in the design and construction of boilers, in their maintenance and inspection, and in the general conduct of manufacturing operations.

Although, as has been indicated, the returns of investigations under the Boiler Explosions Acts are open to the objection that they are apt to produce an impression which is the precise opposite of actual facts, still there is little doubt that many of the investigations into accidents to other kinds of steam-apparatus besides actual steam-boiler explosions are of service, and if they were properly distinguished in the returns which are made, and they were not used for improper purposes, there would be no objection to raise against them.

Analysis of Returns.—Fig. 3 (Plate I.) gives particulars of the nature of the accidents investigated from the year 1882-83 onwards, the totals of the accidents investigated being, of course, identical with those shown in Fig. 1 (Plate I.), but the numbers of the different classes of accidents are shown separately.

The first line "A" shows the actual explosions of steam-boilers; and the figures given are, of course, identical with those shown in Fig. 1 (Plate I.). The total number for the 16 years, 1882 to 1898, is 465, or an average for the period covered of 29 per annum. These will be considered in further detail later.

Collapse of Furnaces or Combustion Chambers without Serious Rupture.—The second line "B" (Fig. 3, Plate I.) shows the number of collapses of furnaces or combustion-chambers without serious rupture, which were investigated under the Boiler Explosions Acts. The total number from 1882 to 1898 is 40, or an average of 2·5 per annum. This is a class of accident which varies from very slight distortion of the plates to serious bulging, but in the cases recorded under this heading such bulging or deformation were accompanied only with more or less severe leakage. The cases of collapse with serious rupture of the plates are included in explosions-line "A." Many occurrences of this kind happen, in the ordinary course, in the conduct of works where numbers of boilers are in use. Such collapses generally are due to overheating at the furnace parts of boilers, owing to deficiency of water, accumulation of deposit or grease on the water-side of the plates, leading to overheating of them. Where the furnaces and combustion-chambers are in good order and not wasted or constructed of brittle plates, in the majority of cases, the distortions take place without leading to any serious rupture, and in some cases without leading to any rupture or any outrush of steam at all.

Leakage by Wasting-through of a Small Hole or Fracture.—The figures given on line "C" (Fig. 3, Plate I.) include a class of unimportant accidents, often slight fractures leading to a somewhat severe leakage and the gradual lowering of the boiler-pressure or the corroding through of a deep pitting on the water-side of the plates forming a small hole and resulting in the more or less severe outrush of water and steam. The total numbers from 1882 to 1898 was 108, an average of 6·7 per annum. Such defects in land-boilers, which are situated in an open space, where the out-rushing steam could rapidly escape, are usually not of serious importance, but when they occur on shipboard, or in other confined spaces, any such severe leakage or outrush of steam may cause great danger to life, and by putting a boiler out of action may endanger the ship. It will be observed that the number of occurrences of this kind reported from 1891 to 1898, and therefore including those on steamboats was 73 or 10·4 per annum. It is quite possible that in the course of time, as the Boiler Explosions Acts become more widely applied to such trivial accidents, the returns of them may be still further increased, leading to an unnatural and misleading inflation of the statistics.

Collapse and Rupture of Smoke-tubes or other Small Tubes.—There were 83 cases of this kind (line D, Fig. 3, Plate I.) in the years referred to, an average of 5·2 per annum. The figures given on this line largely refer to the collapse and rupture of small smoke-tubes, such as those of tramway-boilers, and locomotive and similar boilers. A great majority of the cases are those of failure of tubes of tramway-boilers. The boilers of steam-tram engines, as used hitherto, have largely been small boilers of the locomotive type, and the smoke-tubes have generally been of brass, or similar metal. In the ordinary course of working, wasting away on the fire-side of the tubes takes place, caused by chemical action reinforced by mechanical abrasion of the tubes, owing to small portions of coke and other fuel used being blown against the surface of the tubes. The wasting, too, generally takes place near the firebox-end of the tubes, and when the tubes fail, the outrush of steam is mainly into the firebox. The spaces about these engines are often confined, and consequently this out-rush of steam has occasionally resulted in loss of life, owing to the attendant not being able to get away.

This class of accident is one which necessitates great care on the part of those who have the supervision of the boilers, to entirely prevent. The tubes themselves should be regularly tried by a prodding tool, or some similar appliance, and also should be regularly withdrawn, carefully examined, and weighed, so as to ascertain whether there is any serious reduction of weight.

Failure and Explosion of Steam-pipes and Valves.—The next line "E" (Fig. 3, Plate I.) includes two main classes of accidents of this kind, that is to say, failure of pipes and valves on shipboard and failure of pipes and valves on land.

There were 125 cases from 1882 to 1898, an average of 7·8 per annum. Since steamships were included, that is the last 7 years, from 1891 to 1898, there have been 93 cases, an average of 13·3 per annum. This increase is due, mainly, to the considerable number of cases of failure of copper steam-pipes on ships.

Accidents to Steam-pipes on Shipboard.—The general practice hitherto on shipboard has been to use copper pipes for conducting the steam from the boilers to the engine. The idea is that copper, being a ductile and flexible metal, will give way as required by the movements of the boilers and engines, owing to the straining of the vessel and expansion and contraction and similar causes, without causing damage to the pipes or the valves.

The reports of investigations under the Boiler Explosions Acts of the failures of pipes and valves on shipboard have tended to discredit the use of copper pipes for this purpose. The pipes have failed at the brazed joints, also at the connexions of these to the flanges, and also in many cases where they have been supposed to provide for flexibility and ductility, they have appeared to be brittle and rigid and unsuitable for the object desired. In some cases, the failure of the steam-pipe in the enclosed space of the stokehold and engine-room has caused most serious loss of life.

The general result has been to discredit the use of copper pipes for high steam-pressures, unless they are strongly reinforced by wrapping with steel wire, or in some similar effective way. So far as can be seen at present, however, it would appear that mild steel welded pipes with flanges suitably welded on, or otherwise satisfactorily connected, are much more reliable than copper for the purpose of conducting high-pressure steam, when properly arranged so as to provide for expansion.

Accidents to Steam-pipes and Valves on Land.—These accidents include a large number of cases where cast-iron pipes and cast-iron valves have failed. Generally, the cause of this failure has been either undue rigidity and want of provision for the slight movements of expansion and contraction, or the accumulation of water in the steam-pipes, leading to water-hammer and fracture of the pipes.

Water-hammer.—The bursting of valves and pipes, owing to water-hammer, has generally taken place when an attempt has been made to drain the pipes of an accumulation of water, while the steam was in the pipes and the boiler junction-valves were opened.

Under such circumstances, usually when the water, in being drained out, had fallen to a level at which the steam reached to a considerable surface of it, rapid alternating condensation of the steam and movement of the water took place, resulting in a body of water or water-bullet being projected along the pipes, and bursting the valve or bend, whichever first obstructed its motion.

Such accidents may be prevented by the observation of proper precautions, both in the arrangement and working of the pipes. Steam-pipes should be arranged with a fall, to drain to a definite point, and should be provided with a good steam-trap there which is regularly looked after, or else with a drain which is regularly opened, so that there may be no accumulation of water in the pipes. In no case should an accumulation of water be drained from steam-pipes, while the steam is in the pipes. If water has been allowed to accumulate in the pipes, then the boilers should be shut off for the time being while it is draining away; otherwise great danger of formation of water-hammer may exist.

Rigidity of Pipes.—In very many cases, steam-pipes are put down without any due consideration of the changes which take place in their length and form, owing to the alterations of temperature, when steam is admitted to them. An elongation of about ¼ inch in 10 feet, due to the difference of length when hot and cold, ought to be allowed for in designing pipe-ranges. If the pipes are not so arranged as to have the requisite flexibility, an equivalent amount of compression is caused in the pipes, leading to straining at the joints, leakages at bends, fractures and other defects. It is generally preferable to provide for such expansion by making the connecting-lengths from the steam-main to the boiler of suitable length, so that they move or spring as much as is required, and also by providing in the main range itself properly arranged bends, which will allow movement, without causing undue straining or leakage at the flanges.

Copper expansion-joints and gland expansion-joints are doubtful expedients. Much better permanent work may be done by suitably planning the form and arrangements of the pipes and bends.

Explosions of Kiers, Stills and Similar Vessels.—The cases reported from 1882 to 1898 are 95, or an average of 5·9 per annum. The figures given in line "F" (Fig. 3, Plate I.) include explosions of all such vessels as use steam for manufacturing purposes, such as straw-boilers, rag-boilers, kiers, steam-jackets, ironing-machines at laundries, steam-pans and similar apparatus. Generally, the cause of these accidents has been weakness of the vessels themselves, often combined with the absence of the provision of proper safety-valves between the vessels and the boilers.

It has been common to look upon such vessels in the same light as the ordinary domestic kettle is considered, namely, that the vessel is to be used until it is worn out and then replaced by another. The fact that explosion is liable to occur with vessels of this character has generally not received the attention which it deserves, even from persons who recognize fully the risks attendant on the use of steam-boilers.

In many cases, such vessels are made suitable for working at comparatively low pressures, such as 20 lbs. per square inch, while the boilers to which they are connected, are worked at 60 or 70 lbs. per square inch. Under these circumstances, the pressure from the boiler has accumulated in the vessel, frequently leading to explosion of it. Sufficient care, too, has not been exercised in the design of the vessels, with the view of meeting the pressure to which it was intended to subject them.

Generally the best mode of preventing accidents of this kind, is to have the vessel sufficiently strong to withstand the maximum pressure of the boiler with which it is connected. If, however, this is impracticable, then, between the low-pressure vessel and the boiler, should be interposed a reducing-valve, and between the reducing-valve and the low-pressure vessel, there should be fixed on the steam-pipe a good dead-weight safety-valve, loaded to the pressure to which the low-pressure vessel is suitable. The safety-valve itself then would act as a relief and also as an alarm in case the reducing-valve became inoperative, as is sometimes the case.

Explosions of Feed-water Heaters and Fuel-economizers.—The cases of explosion of feed-water heaters and fuel-economizers reported are 13, or an average of 0·9 per annum. This class of explosion has not been frequent, but still has been sufficiently numerous, compared with the number of apparatus of this kind in use, to show that careful attention is required to the various details of the fittings, and arrangement of the safety-valves of both feed-water heaters and fuel-economizers, in order to prevent serious risk of explosion.

Failure of Manhole-doors and Mudhole-doors, Joints, Blowing-out of Plugs, Stays and Rivets.—There were 111 cases of failure of manhole-doors and mudhole-doors, joints, blowing-out of plugs, stays and rivets reported from 1882 to 1898, or 6·9 per annum. The most numerous class of accidents given under this head is the failure of manhole-doors and mudhole-doors, and of the joints between these doors and the mouthpieces or frames on the boiler. In a number of cases, the doors themselves have cracked or failed. The doors which failed were constructed of cast-iron, and burst, owing, probably, to cracks started, by the strain of screwing to close the joint.

In the course of putting the doors on to the boiler and taking them off, they are often subjected to force, bending and straining, and also in screwing up, frequently great strains are put on the flanges, which lead to incipient fracture, and afterwards to failure of the door. It is very much better that the door should be constructed of pressed or cast-steel or wrought-iron, materials, which are better fitted to withstand the knocking about to which the doors are subjected.

Joint Failures.—The high figures given in recent years under this head (81 cases from 1891 to 1898, or an average of 11·6 per annum) are, however, mainly due to the failure of mudhole and manhole-joints on shipboard. Most of these accidents were caused by an unsuitable form of packing being used for making the joints between the internal mudhole-cover and the frame on the boiler. In many cases, round packing has been used, and when the steam-pressure has risen, the packing has been blown out, resulting in an outrush of steam and water into the confined stokehole, sometimes causing very serious injuries and loss of life. Round packing should never be used for this purpose. The jointing material of manholes and mudholes should be kept as thin as possible; in no case should it exceed $\frac{1}{8}$ inch, while it is preferable that it should be kept not thicker than $\frac{1}{16}$ inch, and if the manhole-faces and the mudhole-faces are not true enough to make a good joint with this thickness of jointing material, they should be trued up rather than use a thicker material.

In many cases, the spigots of the internal mudhole-covers were a loose fit in the mouthpiece. This of course permitted the jointing material to be blown out more easily when the joint failed. It is very much better always to take care in the case of new boilers that the spigots of the mudhole-covers are a good fit in the mouthpieces, so that even if unsuitable packing were used for making the joint, there will be no danger of a serious accident.

Explosions of Hot-water Circulating Boilers.—From 1882 to 1898, the total number of explosions of hot-water circulating boilers was 81, or an average of 5·1 per annum. The figures given on this line, "*I*" (Fig. 3, Plate I.), as will be seen, are very irregular and erratic, in a number of years there being no explosions at all, while from 1892 to 1895, the average was 20·7 per annum. The cause of the irregularity is that these explosions are mainly due to freezing of the outlets. They, therefore, tend to occur more in winters with hard frosts than at other times. Mild winters may, of course, pass without any explosions being caused in this way.

Hot-water circulating boilers are used, either for heating water or for heating buildings, by means of circulating-pipe arrangements. In ordinary methods of construction, boilers of this class are only suited to withstand the low uniform pressure due to the water-column to which they are subjected. Whenever pressure accumulates in them, they are liable to explode with destructive effect.

The principal cause of the explosions shown in the figures given was the freezing of the circulating-pipes. This freezing generally occurred on weekdays in the case of church and chapel boilers, and during the Christmas holidays of schools and similar institutions.

On the boilers being fired up, the outlets being sealed, the pressure simply increased until it was sufficiently high to burst the boiler, resulting frequently in considerable damage to the surrounding property and often in loss of life.

The explosions of domestic boilers, owing to the same cause, are much more numerous than those given, but domestic boilers are specially excepted from the Act.

The proper means of preventing explosions of this kind is to take care that every such boiler is provided with a good deadweight safety-valve, which can be regularly tested and is frequently looked at and kept in good order, and it is also desirable that the boilers should be regularly inspected.

EXPLOSIONS OF STEAM-BOILERS.

Under the head of explosions of steam-boilers are included the actual explosions of steam-boilers, that is, boilers used for generating steam.

Actual Explosions of Steam-boilers which are included in Operation of Acts.—For the purpose of throwing a little more light on the nature and cause of these explosions the total figures for the last 4 years, from 1894 to 1898, have been analysed, and are set forth in detail in Figs. 4 and 5, (Plate I.). Fig. 4 shows the causes from which the explosions for the last 4 years referred to arose, and Fig. 5 shows the description of the boilers which exploded.

Causes of Explosions.—In considering Fig. 4 (Plate I.), it will be observed that the causes of explosions are divided into two main groups, namely, (1) explosions arising from defective condition, and (2) those which are due to mistakes, negligence, or mismanagement on the part of persons in charge of the boilers.

External Corrosion.—Of the causes of defective condition, external corrosion is responsible for the greater number of cases. External corrosion is simply rusting or oxidation of the plates, and is due to leakage or moisture of the surroundings of the boiler, resulting in wasting the plates away. One of the commonest causes of external corrosion in boilers set in the open air with brickwork, and exposed to the ordinary climatic conditions, is the brickwork becoming wet either from inefficient draining of the ground or from rain, and the brickwork absorbing this moisture keeps the surface of the plates constantly moist, leading to comparatively rapid wasting.

The proper mode of preventing external corrosion of this kind is to keep the brickwork about the boiler as dry as possible, by arranging it so that the rain will run away from the boiler and not towards the boiler; and also by taking care that the drains do drain the water away from the boiler and do not allow it to accumulate there; and finally by regularly baring or removing the brickwork in places, so that the actual condition of the plates may be seen.

To reduce the risk of this kind of defect to a minimum, boilers should be protected by houses, and set with as small a surface of brickwork in contact with the plates as is practicable. Brickwork coverings should be avoided, and the flues should stand up clear of the ground and should not be sunk in it.

Intermittent Working and External Corrosion.—Another common cause of external corrosion arises from the dampness due to intermittent working. Boilers which are continuously working and are kept warm are, of course, less liable to deterioration from this cause.

Small boilers, particularly vertical boilers and others which are used occasionally, frequently suffer owing to external wasting, arising directly from the intermittent nature of their work. The boiler ceases work, becomes cold, moisture is condensed on the surface of the plates; and in some cases (in vertical and portable locomotive boilers particularly), ashes are left on the firebars, absorbing moisture and lying against the plates, keeping them moist and leading to rapid wasting. This cause is responsible for a considerable number of explosions.

External corrosion is also often caused by moisture due to leakage from a seam or a joint. If such leakage is beneath the brickwork covering or on the seatings, the conditions for corrosion are very favourable, and wasting over considerable areas sometimes results. The way to prevent wasting of this kind is to give close attention to leakages in their incipient stages before they become of a serious nature, and to keep down the thickness of brickwork in contact with the plates.

Internal Corrosion.—The figures shown on the next line (Fig. 4, Plate I.) are those of the number of explosions due to internal corrosion. Internal corrosion or wasting away of the plates owing to the action of the feed-water, is a form of deterioration to which all boilers are not liable, as it depends entirely upon the constitution of the feed-water. Some feed-waters, although such are not common, have no action whatever on the plates, and after a boiler has been used with them for 20 or 30 years the surface of the plates will be found to be practically as good as when the plates left the rolling-mill. In other cases, where the feed-waters are impregnated with acids or other corrosive constituents, the wasting of the plates may be slow or rapid, and it will assume various forms, according to the type of boiler, the way in which it is used, and the nature of the feed-water.

The only way of entirely preventing wasting of this kind is the use of non-corrosive feed-water. Usually, if the water is corrosive, it is only possible to check its tendencies to a greater or less degree by the use of various alkalies or other chemical means.

Internal Grooving.—One of the most dangerous forms of internal corrosion is that indicated by the following line (Fig. 4, Plate I.), namely, internal grooving. This, when it takes place at the seams of a boiler, reduces the strength of the boiler at one of its most vital parts. The proper means of checking the progress of this corrosion or grooving requires careful consideration in each case, and it is always necessary (whether the corrosion is checked or not), that all the vital parts of the boiler should be thoroughly cleaned so that they may be regularly examined, and the actual condition of the plates ascertained.

The modern system of constructing boilers, namely, with the shell in rings of one plate each with the longitudinal seams above the water-level, avoids the risk of internal grooving at the longitudinal seams.

General Deterioration.—The figures given on the next line—general thinning, internal and external—are those which relate generally to boilers which have been wholly neglected. Frequently such boilers have been intermittently worked, leading to wasting on the fireside, and have been used at the same time with corrosive water.

Seam-rips and Old Fractures.—The next line (Fig. 4, Plate I.) shows the figures due to seam-rips and old fractures. Explosions arising from this cause are generally those of externally-fired boilers. These in past years were much more numerous than they are at present, and seam-rips are becoming a less common cause of boiler explosions. The fractures are largely due to the strains peculiar to the type of boiler, and also in part to the fact that many of these boilers were constructed 20 or 30 years ago, when the material and methods of boiler-construction were much less perfect and reliable than they are at present, and in many cases the explosions have resulted owing to straining or incipient fracture being actually set up in the course of manufacture, leading ultimately many years afterwards to the explosion of the boiler.

Weak Flue-tubes.—Among the explosions resulting from defective construction, weak flue-tubes in earlier years used to be a very common cause (Fig. 4, Plate I.). In the 4 years under consideration, the number of cases directly attributable, however, to this cause is not large. No doubt, many of the older boilers in which the flue-tubes are weak are gradually being replaced year by year by more modern types. Nevertheless, in some districts numbers of these boilers still survive, and are working at pressures which do not allow a satisfactory margin of strength according to modern standards.

The flue-tubes in these cases were plain flue-tubes constructed in the old manner, without cross-tubes, and not strengthened at the ring-seams by stiffening or expansion-hoops, or by flanged seams such as are now commonly adopted.

In the course of Board-of-Trade investigations, which have been held since the passing of the Boiler Explosions Acts, the desirability of strengthening flue-tubes of weak original construction by means of angle-hoops or some other similar method has been repeatedly pointed out by the commissioners who held the formal enquiry. In some districts, this has had very satisfactory results, in bringing about an improvement in the strength of the boilers in this particular.

Generally, it is desirable that flue-tubes should not have a greater length than 10 feet without a strengthening hoop, or angle-hoop, or flanged seam. Tubes which have long lengths unsupported or unstiffened are liable to become gradually oval, and finally to fail by collapse and rupture without warning, and with very serious results.

Explosions arising from Mistakes, Negligence, or Mismanagement—Over-pressure.—Explosions arising from over-pressure and those which are grouped under this head, are such as are not attributable to defective condition of the boiler proper, but which were due to the inefficiency or defectiveness of the safety-valve arrangements, and which resulted in an accumulation of rise of pressure in the boiler until it reached the bursting pressure.

Explosions of this kind are generally the most disastrous in their results, the rupture of the boiler and the projection of the fragments and hot water and steam being always of a most violent character.

Safety-valves.—Generally the safety-valve arrangements on large boilers of the Lancashire type, and similar boilers fixed in position, are comparatively satisfactory, being usually of the dead-weight class, or the open lever and weight description. In the case, however, of small vertical boilers and boilers of the portable locomotive type, spring safety-valves are very commonly in use, as they naturally suit the portable character of the boiler better than safety-valves loaded by weights.

Spring safety-valves require much greater attention than safety-valves which are loaded by weights. In the first place, the springs are liable to become deranged, and, secondly, many of the spring-loaded valves are badly designed, and are not provided with adequate means of testing.

Lever and Spring-balance Safety-valves.—One of the commonest causes of explosion due to over-pressure lies in the use of lever safety-valves loaded by means of a spring-balance, the load on which can be adjusted by screwing a nut round. Such nuts are often screwed round by the attendant when the valve is not properly ferruled, resulting in the valve being actually locked fast, so as to be entirely inoperative, or very greatly over-loaded. Spring-balance safety-valves ought always to be properly ferruled, and should be carefully tested regularly, so as to ensure that the valve may have a proper lift, and may lift freely at the pressure desired.

Safety-valve and Junction-valve on the same Branch.—Another cause of explosions from over-pressure which was more common in past years than at present, was the connexion of the safety-valve of a boiler with the same opening as the junction-valve. In such cases, when the boiler has been connected to another boiler, which was under steam, very frequently the boiler-cleaners have blocked the opening to the safety-valve in order to prevent inconvenience from leakage at the junction-valve when they were cleaning the boiler; and the plug being left in, the safety-valve, of course, was shut off from the steam-space, with the result that explosion followed when the boiler was restarted.

In the case of small vertical boilers, which have supplied a number of these explosions from over-pressure, even at the present time it is a common practice to connect the junction-valve and the safety-valve to the steam-space by the same branch.

The danger of plugging before mentioned does not exist in this case, but as is wellknown, these small vertical boilers are very liable to priming, and the mud and deposit carried past the safety-valve opening in this way frequently leads to the safety-valve sticking, causing a jam, and rendering the boiler very liable to explosion from over-pressure. A serious explosion from this cause is included in the list.

It is to be generally remarked that these small vertical boilers are, as a rule, in the charge of less careful attendants than large fixed boilers, and it is therefore all the more desirable that their fittings should be of a kind which cannot be easily tampered with or rendered unsafe, and which will remain safe with a less amount of skilled attention than is required in the case of ordinary types of fittings.

Explosions due to Deficiency of Water.—Although a large number of cases of deficiency of water occur every year, which merely cause bulging or distortion of the furnaces, and do not result in explosions, yet a large number of explosions do actually result from deficiency of water. In the case of externally-fired boilers, for instance, deficiency of water leads to the shell-plates, which are subject to the tension due to the internal pressure of steam, being overheated and weakened, resulting in their failure, and numbers of disastrous explosions have been caused in this way.

In the case, too, of Lancashire boilers and other internally-fired boilers, deficiency of water may lead to simple distortion of the furnaces, as before mentioned, but if the furnace-plates are not ductile and the overheating is of a severe character, sometimes serious rupture follows the collapse or distortion of the furnace, with most disastrous results to any one who happens to be standing near the front of the boiler.

The prevention of accidents from deficiency of water depends simply on the care and vigilance of the man in charge of the boiler, assisted by any low-water safeguard with which the boiler may be provided. It is sometimes argued that the provision of low-water safeguards is liable to render men in charge of boilers less careful than they otherwise would be; but experience would appear to indicate that even with most careful men lapses of attention are liable to occur from time to time, and that it is therefore desirable to supplement the attention of the attendant by some good form of low-water safeguard.

Explosions caused by Deposit, Grease and Salt-water.—Generally, the effect of deposit on the water-side of the plates is to produce overheating of a character somewhat similar, though differing in detail, to that which results when the supply of feed-water is deficient or the boiler is short of water.

Such explosions are liable to be of a more serious character, of course, where the deposit is excessive, and the overheating which consequently results is unusually severe. The presence of a little grease mixed with deposit has a surprising effect in increasing the amount of overheating. Very little grease or oil usually when mixed with the feed-water or deposit very soon brings about overheating of the plates, and it is generally best therefore to take care to exclude grease entirely from the feed-water.

From time to time, periods of drought cause the ordinary land supplies of feed-water in some districts to become more strongly impregnated than usual with the scale-forming and deposit-forming matter, increasing the liability to overheating owing to deposit.

The use of salt-water in boilers is very liable to have serious results in the way of overheating, unless care be taken, by regular and frequent cleaning, and also by the daily use of the blow-out, to prevent the water from becoming saturated with salt, and so leading to serious overheating and explosion.

Description of Exploded Boilers.—Fig. 5 (Plate I.) shows the description of the exploded boilers referred to in Fig. 4, which were reported on under the Boiler Explosions Acts, during the 4 years from 1894 to 1898.

The ordinary small vertical boiler with firebox stands far above the other types as regards the number of explosions, and this liability to accident is characteristic of that type of boiler. Of course, the numbers stated for the purposes of comparison would require considering, in connexion with the total number of such boilers which exist in the country.

Comparative Explosion-rate of Different Types of Boilers.—The author made such a comparison* a few years ago, and from the particulars then obtainable, it appeared that for the period of 10 years, from 1885 to 1894, the small vertical boiler with firebox stood far higher than any other type in the relative number of explosions compared with the number of boilers in use. Boilers of this type then showed 48 explosions per 100,000 in use per annum, whereas Cornish boilers showed 15·7 explosions, Lancashire boilers 5·75, and plain cylindrical boilers, externally-fired, 37·2 explosions per 100,000 per annum. These figures give a fair indication of the relative liability of the different types to accident or to explosion, but it is necessary in considering them to take some account of the age of the different classes and other characteristics.

Small Vertical Boilers.—The small vertical boiler with firebox, which is used for quarries, contractors' work, and generally in places where small power is required, and convenience of moving and fixing, and portability are important considerations, is particularly liable to defects of various kinds leading to rapid deterioration. In the first place, the boiler is frequently used intermittently, leading to more or less rapid wasting in the firebox, and this accounts for a considerable number of explosions of these boilers. In the second place, the general construction of the boiler renders it liable to severe grooving of the firebox and shell-crown and similar defects, which again accounts for some explosions. Further, the fittings of the boiler are commonly defective, leading to a number of explosions from over-pressure, as before indicated. Lastly, the boilers are frequently only inadequately attended, again contributing to the total of accidents.

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* "British Types of Land Boilers," *Proceedings of the Cleveland Institution of Engineers*, 1895-96, page 121.

Cylindrical Externally-fired Boilers. — Among the other types shown in Fig. 5 (Plate I.), attention is specially called to the cylindrical externally-fired boiler. This boiler is one of the oldest types of steam-boilers in use in this country, and many old boilers of this description are to be found, in some of the older industries, such as old collieries, and similar works. The liability of this type to explosion, as indicated in the figures before mentioned, is not only due to the inherent peculiarities of the type of boiler, but also to the fact that most of the boilers of this class now existing are of considerable age, probably the great majority over 20 or 30 years old, and consequently their construction is generally characteristic of the time when they were made, and is much less perfect than is now considered to be satisfactory. Many of the boilers were constructed of iron plates of the ordinary quality, being comparatively brittle; the plates were punched and the plates were bent after the holes were punched, setting up in some cases incipient fractures at the seams.

Locomotive-type Boilers.—Boilers of the locomotive type, the explosions of which are included in this list (Fig. 5, Plate I.), are mainly those belonging to private firms, and also include the boilers of the portable-locomotive type, such as are largely used for agricultural purposes. The latter class of boilers is one which generally receives only poor attention, both in regard to the working of the boiler and the fittings, and many of the explosions which occurred arose from neglect of this particular kind. In the case of locomotives, these are of a type similar to the small locomotives used for shunting and other such work. Such boilers are generally difficult to inspect or clean adequately. They are generally covered and concealed externally by their clothing of lagging, tanks and machinery, and when the small sight-holes are opened, only too often it is quite impossible to see through them anything more than a glimpse of a medley of stays and tubes.

It is desirable that in the construction of these boilers more account should be taken of what is necessary for the cleaning and inspection of the boiler.

Water-tube Boilers.—The explosions of boilers of this class have generally not been very destructive to property, but have caused a considerable loss of life in proportion to their number. They have generally consisted of the bursting of the small tubes with a violent outrush of water and steam, or cracking or failure of the headers by which the tubes are connected to the upper steam-and-water drum of the boiler. Boilers of this class are gaining favour for various purposes, but in order that they may be thoroughly safe and reliable in ordinary working they require careful attention to internal cleaning, so that no damage owing to overheating or accumulation of deposit may occur; and in the matter of construction it is desirable that no parts of these boilers should be made of cast-iron, so as to avoid the risk which exists of cast-iron headers cracking across and breaking with serious results.

Effect of Judgments of Commissioners in Formal Investigations.—Now, although the Boiler Explosions Act originally was an Act only for investigation and enquiry, it empowers the commissioners to order certain persons to pay the whole or a part of the cost of the enquiry. This power, and that of blaming or censuring different individuals who may be found responsible for boiler explosions, has led to a certain corrective or punitive effect of the Act, and this in some districts has been most marked in producing considerable improvement in the construction, maintenance and working of boilers. In certain districts where, before the Boiler Explosions Acts were in force, boilers were treated most negligently, two or three rigorous formal enquiries have sufficed to bring home to the boiler-owners and those responsible for working them, a proper sense of their responsibilities, resulting in an improved standard all round. This is among the most beneficial of the results of the working of the Acts.

The punitive or corrective side of the Boiler Explosions Acts has supplied in some directions a much-needed stimulus to exertion in the direction of improvement in both the construction and treatment of the boilers.

In the description of the material causes of boiler explosions, Figs. 4 and 5 (Plate I.), one step of the investigation only is complete. The further question arises in these enquiries under the Boiler Explosions Acts, namely, who was responsible for the particular form of deterioration or defect or negligence which led to the explosion.

Personal Causes of Explosions.—*Ignorance.*—Among the most common of the personal causes of explosion, leading to many of the material causes before referred to, is ignorance on the part of the boiler-owner or the person using the boiler, with reference to everything concerning it. By such persons, the boiler has been considered as a common machine, much as a lawn-mower would be, or anything else which is not liable to cause accident, and has been worked with a complete disregard of any possibilities of danger to life or limb. In such cases, the Board of-Trade commissioners have repeatedly laid it down in giving judgment and blaming the person responsible, that persons who work steam-boilers are bound to take all necessary reasonable steps in order to ensure that they may be worked with due regard to the safety of the public and of those who are engaged about them.

These judgments and the imposition of the costs have had a most salutary effect, as before indicated, in certain districts, and it is only to be regretted that they do not sufficiently often reach the most ignorant, who are the persons to whom they would be the most beneficial.

Incapable Practical Man.—Another common cause of explosion is the unqualified practitioner, that is to say a man who represents himself capable of inspecting a boiler and gives an opinion in reference to its safety misleading the boiler-owner, while this particular man is really quite unqualified to determine the safety of the boiler or to give the opinion that he expressed. In a large number of cases, it has been shown, in the course of the investigations, that many ordinary boiler-makers, engine-fitters, and similar engine-repairers hold themselves out as being qualified to give an opinion respecting the strength of steam-boilers, while they made no proper inspection and no calculations whatever in regard to the boiler's working-strength and pressure. The so-called practical man, whose personal influence and standing with the boiler-owner was often sufficient to lead the latter to suppose that the practical man was able to give an opinion, commonly makes no calculations at all, but judges the boiler by rule-of-thumb without any detailed examination, leading directly to explosion and disaster by creating a false sense of security when the boiler is in bad condition. Such persons have been blamed repeatedly by the commissioners and ordered to pay costs, and it is to be hoped that the judgments which have been given will have some salutary effect in checking the practice.

Necessity of Special Training for Boiler-inspection.—While it has to be recognized that to determine the strength of a boiler requires a practical man, it is also to be recognized that an ordinary engine-constructor or boiler-maker who has had no special training in regard to the particulars taken to determine the safety or otherwise of the boiler, usually cannot be relied upon to make a complete examination of it, and in all cases careful calculations as to the strength of the boiler are essential before any definite opinion can be given as to its safety or otherwise.

Dealers in Second-hand Boilers.—Boiler-brokers, or dealers in second-hand boilers, too, have frequently figured in the formal investigations of the Board of Trade. It would appear to be common among certain of these persons to deal in boilers as they deal with their other machinery, without any special consideration of the safety or otherwise of a boiler, but often not hesitating to make a statement that it is good and sound without definitely having it ascertained whether this is correct. The judgments of the Board-of-Trade commissioners in these matters have laid stress on the importance of carefully examining second-hand boilers before purchase, and the desirability of having this examination made by persons who are able and specially trained to do it.

Second-hand boilers, at the best, always carry an element of doubt concerning their exact condition, as, even with the best examination, it is not always practicable to determine all details in reference to the original construction of the boiler, treatment, and other points of its history which affect its future probable life and margin of safety. It is all the more desirable, therefore, before any such boiler be used, that it be subjected to as close and complete an examination by a well-qualified person as is possible.

Boiler-repairers.—The judgments of the commissioners, too, have laid a certain responsibility upon boiler-makers and repairers. In a number of cases, it has appeared that a general order has been given by the boiler-owner to the boiler-maker to see that the boiler has been put in good order, while the boiler-maker apparently understanding that only certain repairs had to be executed has executed these without ascertaining whether the boiler is safe, so that, arising out of misunderstandings of this character, the boiler has been set to work with one part partially repaired and others left in a dangerous condition, the result being a serious explosion. In such cases, the commissioners have, where they thought that sufficient care had not been exercised by the boiler-maker, blamed them for the explosion. These judgments have shown the desirability that, in all cases, whenever boiler-makers or boiler-repairers are ordered to repair a boiler, they should, if the boiler has not already been examined by a well-qualified person, take care that they do not incur any doubtful responsibility by carrying out inadequate repairs to a boiler which is seriously defective in other ways.

Management of Works.—Among the most important of the judgments of the commissioners are those in which they have taken into consideration questions of works' management. It has in a number of such cases appeared that there was an indefinite and undetermined line of responsibility existing as regards the working and control of the boilers on the part of the boiler-attendant and those in superior positions, and no definite instruction was given as to who was responsible for the actual maintenance and working of the boiler, and to whom the attendant was to refer for instructions. There is no doubt that the manufacturer who produces any article is bound to regard the boiler as part of his steam-plant, which is to be put in operation when required just as other machines are done; but it has to be remembered that in the case of ordinary manufacturers, whereas many of the machines may wear out and parts of them give way owing to wear and tear, without material risk to those about them, the deterioration of a boiler is accompanied by more serious results, and therefore greater care is required, both in its control and working. It is impossible, of course, in an ordinary works or undertaking that as a rule there should be a complete system of the devolution of responsibility clearly defined by rule and regulation, as is supposed to exist in a Government department. At the same time, it is most important and desirable that the exact extent of the responsibility should be clearly defined, so that boiler-attendants know for what they are responsible, what they have to do, and to whom they are to look for advice and direction in case of any difficulty.

Inspection of Boilers.—In connexion with the inspection of boilers, the principle laid down by the commissioners from time to time points to the necessity of every boiler being examined regularly by specially trained boiler-inspectors, and also in addition to this, to the careful observation and regular cleaning and maintenance of the boiler by those who are in charge of the working of it. Such inspection and regular examination by specially trained men can be readily obtained from the insurance companies and inspection bodies, and this regular inspection, combined with proper care and control on the part of those in charge of the boilers, has been shown by experience to be quite adequate to prevent all those explosions which arise from preventable causes.

General Results of the Working of the Acts.—The working of the Acts, as a whole, has been beneficial. It has resulted in technical information being obtained, with reference particularly to a variety of accidents other than steam-boiler explosions, which did not come before public notice before, and also by the decisions of the formal enquiries, it has generally tended to raise the standard of steam-boiler construction and working in this country. The direct and indirect effect of these decisions has contributed in a marked degree to the improvement which has taken place in recent years in the working and management of boilers, and so far as improvement is possible in these matters a further improvement may be expected in the future from these operations.

Steam-engines (Persons-in-Charge) Bill.—There are, however, from time to time proposals brought forward, based largely on the statistics obtained from the working of these Acts, to impose various restrictions both as to the working of boilers by the men in charge of them, and as to the inspection of them.

With this object, the whole of the statistics of the working of the Boiler Explosions Acts have been used in support of the Steam-engines (Persons-in-Charge) Bill, and also of the Boiler Inspection and Registration Bill.

The Steam-engines (Persons-in-Charge) Bill proposes to render it compulsory to employ certificated men to take charge of, and to work steam-boilers. It is very possible that the actual objects of such a Bill are different from the ostensible motive, namely, the simple prevention or reduction of liability of boilers to explosion.

Whenever the statistics of the working of the Boiler Explosions Acts are used it is essential in order that their correct bearing may be understood that the nature of them should be clearly borne in mind and the fact remembered that they point to a continuous and steady diminution of the number and severity of explosions in the United Kingdom, and therefore any ground for legislation, even at the present time, tends to become narrower and narrower year by year.

So far as the desirability of making the employment of certificated men compulsory for the working of steam-boilers is concerned, it is to be observed that the amount of technical knowledge required by the fireman of a boiler for the safe working of the boiler, is not great. The question is one rather of a small amount of technical knowledge with reference to the use of the various fittings and the regular testing of them, and a considerable amount of care and vigilance on the part of the man. He has to take care that his safety-valves are free, and to test them regularly; to ensure that his water is at the proper height in the glass; to see that his boiler is fed regularly; to systematically observe his pressure-gauge, and to see that the steam-pressure is kept at the proper point.

These are matters which certainly involve a little technical skill, such as can be easily acquired by an intelligent man, but which depend for their prompt and reliable carrying out much more upon the character of the man than upon whether he has a large amount of technical knowledge or not.

The compulsory employment of certificated men to take charge of the working of steam-boilers would certainly render it extremely difficult in certain contingencies to conduct large undertakings, while on the other hand it is very questionable whether any material reduction would be effected of those explosions which arise from mistakes on the part of the boiler-attendant.

Boiler Inspection and Registration Bill.—The other Bills, which are regularly brought forward with reference to boiler-inspection and registration, and propose to make it compulsory throughout the country that boilers should be inspected, have also been largely based on the statistics of the working of the Boiler Explosions Acts issued by the Board of Trade. It is largely due to the misleading character of these statistics which, on the face of it, show a considerable increase in serious boiler-explosions, that some degree of consideration has been given to these proposals. Actually the figures, as shown on Fig. 2 (Plate I.) particularly, show how considerable an improvement has taken place in this country during the past 20 or 30 years, and rather tend to indicate that the present state of affairs is satisfactory than that any drastic legislation is required in this matter.

TABLE I.—SHOWING THE NUMBER OF ACCIDENTS INVESTIGATED BY THE BOARD OF TRADE UNDER THE BOILER EXPLOSIONS ACTS, AND THE NUMBER OF THESE ACCIDENTS THAT ARE ACTUAL EXPLOSIONS OF STEAM-BOILERS.

Year.	Number of Accidents.	Number of Explosions of Steam-boilers.	Year.	Number of Accidents.	Number of Explosions of Steam-boilers.
1882-83	45	33	1890-91	72	32
1883-84	41	24	1891-92	88	34
1884-85	43	32	1892-93	72	25
1885-86	57	35	1893-94	104	26
1886-87	37	19	1894-95	114	31
1887-88	61	34	1895-96	79	24
1888-89	67	27	1896-97	80	25
1889-90	77	34	1897-98	84	30

TABLE II.—SHOWING THE NUMBER OF EXPLOSIONS OF STEAM-BOILERS ON LAND, FROM 1866 TO 1897.

Year.	Number of Explosions of Steam-boilers.	Number of Persons Killed.	Year.	Number of Explosions of Steam-boilers.	Number of Persons Killed.
1866	74	77	1882	38	36
1867	42	59	1883	42	22
1868	53	64	1884	36	24
1869	60	86	1885	36	30
1870	58	75	1886	32	30
1871	43	49	1887	33	21
1872	62	34	1888	33	18
1873	58	54	1889	36	19
1874	65	71	1890	41	19
1875	46	67	1891	32	12
1876	40	91	1892	27	11
1877	43	46	1893	27	9
1878	49	48	1894	25	10
1879	36	41	1895	26	36
1880	28	69	1896	18	6
1881	34	40	1897	18	5

TABLE III.—SHOWING THE CAUSES OF EXPLOSIONS OF STEAM-BOILERS, REPORTED UPON UNDER THE BOILER EXPLOSIONS ACTS DURING THE 4 YEARS, 1894-98.

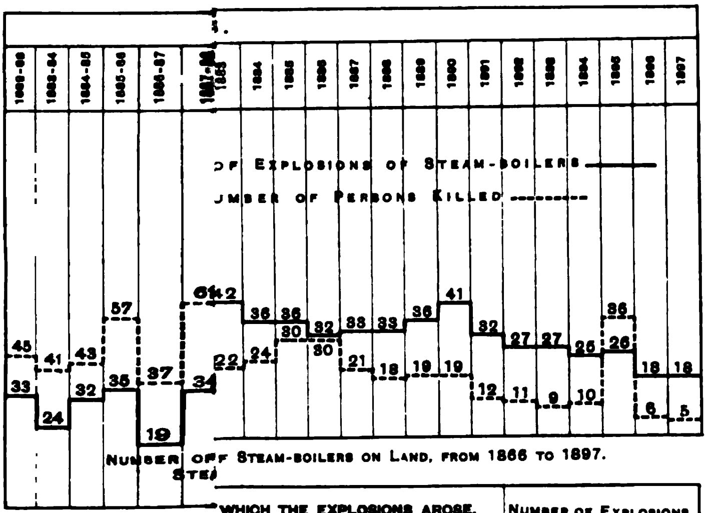
Causes from which the Explosions arose.	Number of Explosions.	
Defective condition:—		
External corrosion	26	
Internal corrosion	9	
Internal grooving	4	
General thinning, internal and external	14	
Seam-rips, old fractures	4	
Defective construction	3	
Weak flue-tubes	3	
Defective stays	1	
Rigid blow-out pipes	1	
	—	65
Mistake, negligence and mismanagement:—		
Over-pressure	16	
Deficiency of water	19	
Deposit, grease and salt-water	8	
Screwing up water tube boiler cap under pressure	1	
	—	44
Explosions attributable to a combination of causes	1	
	—	1
Total Explosions		110

TABLE IV.—SHOWING THE DIFFERENT TYPES OF STEAM-BOILERS, THE EXPLOSIONS OF WHICH WERE REPORTED UPON UNDER THE BOILER EXPLOSION ACTS, DURING THE 4 YEARS, 1894-98.

Description of Exploded Boilers.	No. of Explosions of the Different Types of Boilers.	
Vertical, with fire-box	39	
Marine	14	
Cornish	13	
Cylindrical, externally fired	13	
Locomotive-type	12	
Lancashire	11	
Water-tube	5	
Rastrick and vertical (iron-works)	3	
	—	110

TABLE V.—SHOWING THE NATURE OF THE ACCIDENTS INVESTIGATED UNDER THE BOILER EXPLOSIONS ACTS.

Nature of Accidents.	Years.															
	1882-83.	1883-84.	1884-85.	1885-86.	1886-87.	1887-88.	1888-89.	1889-90.	1890-91.	1891-92.	1892-93.	1893-94.	1894-95.	1895-96.	1896-97.	1897-95.
A.—Actual explosions of steam-boilers ...	33	24	32	35	19	34	27	34	32	34	25	26	31	24	25	30
B.—Collapse of furnaces or combustion-chambers, without serious rupture ...	2	2	1	2	3	1	4	9	2	1	1	3	3	2	2	2
C. Leakage by wasting-through of a small hole or fracture	0	0	1	4	0	6	10	10	4	15	9	12	11	8	8	10
D.—Collapse or rupture of smoke-tubes or other small tubes	0	0	1	3	3	3	8	7	4	7	9	8	12	8	4	6
E.—Failure and explosion of steam-pipes and valves	0	0	3	3	2	6	5	2	11	10	7	10	12	16	20	18
F.—Explosions of kiers, stills and similar vessels	7	11	4	2	6	8	5	6	5	9	5	7	5	6	5	4
G.—Explosions of feed-water heaters and fuel-economizers	1	1	1	3	1	1	0	0	1	1	1	0	1	0	0	1
H.—Failure of manhole-doors, mudhole-doors, joints, blowing-out of plugs, stays, rivets, etc....	2	3	0	4	0	1	7	7	6	11	3	15	12	15	13	12
I.—Explosions of hot-water circulating boilers	0	0	0	1	3	1	1	2	7	0	12	23	27	0	3	1
TOTALS	45	41	43	57	37	61	67	77	72	88	72	104	114	79	80	84



Number of Steam-boilers on Land, from 1866 to 1897.

Fig. 1.—Diagram ... investigated by th... Explosions Acts, ... that are Actu...

NATURE

A { Actual Explo... Boi...

B { Collapse of F... Chambers, wit...

C { Leakage by W... Small Ho...

D { Collapse, or ... or oth...

E { Failure and ... Pipes ...

F { Explosions of ... simila...

G { Explosions of ... and Fu...

H { Failure of Ma... hole-doors, ... Plugs, St...

I { Explosions of ...

...which the explosions arose.	Number of Explosions.
...ondition.	
...nal Corrosion.	26
...nal Corrosion.	9
...nal Grooving.	4
...al Thinning— ...ernal and External.	14
... Rips—Old Fractures.	4
...tive Construction.	3
... Flue-Tubes.	3
...tive Stays.	1
... Blow-out Pipes.	1
...ligence, and Mismanagement.	
...ressure.	16
...ency of Water.	19
...t, Grease, Salt-water.	8
...ng up Water-tube Boiler Cap ...der Pressure.	1
...ttributable to a Combination of	1
TOTAL	110

...iagram showing the Causes of Explosions of Steam-...s, reported upon under the Boiler Explosions Acts, during the four years 1894–98.

...of exploded boilers.	Number of Explosions of the Different Types of Boilers.
Firebox.	39
	14
	13
...ternally Fired.	13
...e.	12
...e.	11
	5
...ertical (Iron Works).	3
TOTAL	110

Fig. 3. ...agram showing the Different Types of Steam-boilers, ...sions of which were reported upon under the Boiler ...losions Acts during the four years 1894–98.

The **President** (Mr. J. A. Longden) remarked that so far as the *Transactions* were concerned, the subject of this paper was an entirely new one to the members. Some years ago, he had an 18 inches steam-pipe which burst in the engine-house. Luckily, the enginemen left the lever in an upright position before charging through the window. He was certain that there were more accidents from water-hammer than the members were aware of. Mr. Hiller referred to the fact that water should not be allowed to fall to low levels in the steam-pipes, and that steam should be shut off while the water was being drained from the pipes. This was no doubt good advice, but they could not quite do that with colliery-boilers. Thus, an accident happened down the pit and winding was suspended for a time; water accumulated in the pipes, and accidents then ensued. As far as he could see, the only way to prevent such accidents would be to place relief-valves on the cylinders and steam-traps on the pipes to remove the water. Expansion-joints should be inserted in ranges of steam-pipes: he preferred those of disc-form—two plane-surfaces joined together. He had them made of wrought-iron, and they acted satisfactorily. He had no doubt that the question of inspection was a matter in which Mr. Hiller was greatly interested. To engineers like himself, who had not time to go into boilers, it was a matter of satisfaction that there existed competent persons who looked after such matters. With regard to the desirability of making the employment of certificated men compulsory for the working of steam-boilers, there was not the slightest doubt that trades-unionists would be glad if an Act were passed and no one allowed to work an engine unless he had received a certificate. In Table II., the members would see the great reduction which had taken place in the number of explosions from steam-boilers and of the number of persons killed. With the exception of the figures for 1895, there was a gradual reduction, down to only 5 for 1897. With this wholesale reduction before them, he thought that no one could say that owners were not anxious to take care of the lives of their workmen.

Mr. E. B. **Wain** (Chatterley-Whitfield collieries) said, with regard to the question of water-hammer, it had been suggested when the engines were placed at a distance from the boilers, and a considerable amount of water-condensation took place, that relief-valves should be placed on the pipes so as to neutralize the water-hammer to some extent. He noted, as regards expansion-joints, that Mr. Hiller strongly objected to gland-expansion joints, and it would be extremely interesting to learn why he objected to that kind of joint. He should also like Mr. Hiller's opinion as to joint-failures, as to whether the strong alkaline solutions which are so often used in feed-water had any effect on asbestos-jointing. He had great pleasure in proposing a vote of thanks to Mr. Hiller for his interesting paper.

Mr. W. N. ATKINSON (H.M. Inspector of Mines, North Staffordshire), in seconding the vote of thanks, thought that it would be interesting to know Mr. Hiller's opinion as to the practical effect of the working of the Boiler Explosions Acts; whether the marked reduction in the loss of life was chiefly due to the working of that Act or to some other cause.

Mr. T. VAUGHAN HUGHES (Birmingham), referring to explosions being caused by deposits of grease and salt, asked for a definite expression of opinion as to whether it was wiser in all cases, where possible, to purify the water before being used in the boiler instead of whilst in the boiler. He would also like to know Mr. Hiller's opinion as to the electrolytic method of treatment, which consisted in producing electric action while the water was in the boiler, or before it entered the boiler, so as to cause the solid matter to float or to catch it in a receptacle before it entered the boiler.

Prof. H. LOUIS (Newcastle-upon-Tyne) asked whether Mr. Hiller could give the members any idea of the average increase in steam-pressure during the years comprised in Table II. He took it as undoubted that from 1866 to 1897 the average steam-pressure had been steadily increasing, and if they could get this information so as to form a base-line from which the number of accidents could be tabulated, it might, he thought, be shown that an increase in steam-pressure was accompanied by increase in safety.

Mr. W. J. ORSMAN (Wigan), referring to the question of using acid water, remarked that he had known some works where water had been used containing sulphuric acid, and he had seen several cases where the interior of the boiler and water-pipes had been corroded. Such water required special treatment before passing into the boiler.

Mr. E. B. WAIN asked Mr. Hiller whether steel or iron plates were best able to resist internal corrosion.

Mr. E. G. HILLER, replying to the discussion, referred in the first instance to the question raised by Prof. Louis respecting the pressure at which boilers were worked. He said that, within the last 5 years, the maximum pressures of new boilers used for manufacturing purposes on land had increased to as much as 200 pounds per square inch in

Lancashire and in water-tube boilers, and in exceptional cases to 250 or 300 pounds per square inch. Seven or eight years ago, the maximum pressures would be about 100 to 120 pounds per square inch. Fourteen or fifteen years ago, the maximum pressure was about 80 pounds per square inch. Although he did not think it practicable to plot a diagram showing the relation of boiler explosions to the increase of steam-pressure as suggested by Prof. Louis, it was an undoubted fact that there had been an increase of safety along with the increase of working pressures of steam boilers. This was related to another question which had been raised, particularly by Mr. Atkinson's remarks as to the practical effect of the working of the Boiler Explosions Acts, namely, what are the causes of the increase of safety in the working of steam boilers that has been so marked in recent years. This increase in safety is attributable to the operation of a number of causes, amongst which might be mentioned the working of the Boiler Explosions Acts, the more general adoption of good inspection of boilers, better attendance, and improved construction. The working of the Boiler Explosions Acts had contributed to this very desirable object in a marked degree. The judgments of the commissioners in formal investigations had resulted in an improvement of practice respecting steam boilers in large areas, causing many boiler-owners, who had not hitherto done so, to place their boilers under the inspection of boiler insurance companies, and the operation of the Acts had a stimulating effect upon the boiler insurance companies. Boilers were now worked more carefully than in past years, and a knowledge of what was required to ensure safety was more diffused and better recognized, both by boiler-owners and attendants.

The great improvements that have been made in the methods of construction of boilers had also largely contributed to the greater general safety of working at the present time. Old boilers of inferior construction are gradually and continuously being replaced by better made boilers. Amongst the principal points of improvement in construction, he might mention the use of mild steel plates instead of iron plates, the use of drilling instead of punching for the rivet-holes, and the use of flanged seams in the flue-tubes of boilers. Mild steel plates as now produced were altogether a tougher, more ductile and more reliable material than the average of iron plates such as were commonly adopted in past years, and the use of this tougher material had resulted in a reduced liability to fractures, rips and defects, which had frequently led to disastrous explosions. The drilling of rivet-holes instead of punching had several advantages. It resulted, when the holes were drilled after the plates have been bent to form, in the rivet-holes being absolutely opposite to each other so that there was no need to use the drift to draw the plates together, as was often done when the rivet-holes were punched causing great straining along the seams and often setting up incipient fractures. Further, the drilling of the metal simply removed it, whereas punching not only removed a portion of the metal, but injured to a greater or less degree the plate immediately round the rivet-hole, and the strength of the plate along the seam was thus reduced to a considerably greater extent than the mere removal of the metal at the hole would indicate. Also, in the case of punched rivet-holes, this work was done when the plates were flat and in bending them to the circular form there was often a considerable difficulty in bending the end of the plates, where the rivet-holes had been made, without causing a sharp bend at the part where the rivet-holes had been made. This bending of the ends of the plates in the cases of punched rivet-holes had been responsible in the past for setting up many fractures, resulting years afterwards in serious explosions.

The adoption of flanged seams in the construction of flue-tubes was advantageous in several ways. Flue-tubes constructed in this way were generally made with welded longitudinal seams, and the flanged seam rivets were not placed in the fire, so that a flue-tube was obtained which had no rivets whatever exposed to the flame. This mode of construction was much less liable to leakage than was the old one in which the tubes were made with ordinary lap seams. Of course, flue-tubes constructed with flanged seams were also very much stronger than the old tubes which had no such strengthening in them, and this great improvement practically removed the liability to the gradual deformation of the tube and complete collapse, such as plain unstrengthened tubes were liable to.

It was owing to these improvements in construction that they were now able to use boilers at pressures of from 250 to 300 pounds per square inch, which were much safer than the old types made of iron with punched rivet-holes, even when the latter were working at such low pressures as 30 to 40 pounds per square inch. There had been explosions of the tubes of water-tube boilers, but he could not recollect a serious explosion of the shell of a Lancashire boiler made of mild steel plates with drilled rivet-holes.

He (Mr. Hiller) then referred to the question raised by Mr. Hughes and Mr. Orsman respecting the action of the feed-water and the best method of purifying feed-water. There was no doubt that the most efficient plan, so far as the purification of the water was concerned, was to deal with it before the water was fed into the boiler. This was the plan which was adopted in such apparatus as the Stanhope purifier, the Archbutt-Deeley purifying apparatus, and many others. His experience, however, was that such apparatus required careful supervision, and was generally expensive as to cost of plant and its operation in the way of attendance, chemicals used, and so on, as to put it out of the question in the case of a large number of steam-users. There was no doubt, however, that the water could be purified better before putting it into the boiler than by putting any re-agent into the boiler. Many such re-agents were used, comprising the very varied class of boiler compositions, some of which were efficient, some of no effect whatever, and others injurious. The best plan in all cases, before deciding on the re-agent to introduce into a boiler or the steps to purify the water, was to have it analysed so that advice could be given on a proper basis. Soda introduced with the feed-water, daily and in suitable quantities, was probably the most generally useful of the re-agents commonly employed. Whatever re-agent was used, it would still be necessary to pay attention to the regular cleaning of the boiler, as the general effect of these re-agents was only to soften the scale or deposit, but not to prevent its formation. A question had been asked as to electrolytic action as a purifier of water, but he did not think that our experience was such as to lead engineers to put faith in this action for preventing deposits in steam boilers.

Mr. Wain asked whether steel or iron plates were best able to resist internal corrosion. There was a difficulty in estimating the relative resisting power of steel and iron plates to corrosion. Different kinds of steel plates resist corrosion to varying extents, and the same might be said of iron plates. So far as external corrosion was concerned, they had the evidence of railway engineers that steel rails wasted more rapidly owing to atmospheric causes than iron rails. As regarded steam boilers, the question was one of considerable difficulty, but the general impression on his mind obtained from the consideration of the behaviour of a large number of steel and iron boilers in districts where corrosive feed-water was used, was that steel boilers, as a rule, did corrode more rapidly than iron boilers. It was so seldom, however, that one came into contact with two boilers, one of iron and one of steel, working under exactly the same conditions, that while he thought this general impression to be fairly correct, he should not like to say that it was an absolute fact. Even if it were a fact, that would not be any reason why steel plates should not be generally used, as the advantages resulting from the use of steel plates far outweigh the disadvantages of any slightly increased liability to corrosion. External corrosion was perfectly preventable, and simply required the boiler plates on the outside to be kept dry and free from leakage, damp and moisture. Internal corrosion also could easily be prevented to a considerable degree by using caustic soda or some other suitable re-agent to neutralize the acid action of the feed-water.

He (Mr. Hiller) was unable to give any definite information in reply to Mr. Wain's question as to whether alkaline solutions had a bad effect upon asbestos jointing, and he did not know that serious cases had been met with of the blowing-out of joints which could be attributed to that cause. Most of the serious causes of joint-failure were serious because they occurred on shipboard, where the outrush of steam and water into a confined space resulted in danger to the lives of those near the boiler. Similar accidents had frequently occurred with land boilers, in open spaces, without any serious results. Accidents from the blowing-out of joints had generally taken place where internal covers were used and arose largely from the use of thick and unsuitable packing and also from too great a clearance being left between the spigots of the covers and the mudhole or manhole-mouthpieces. It was certainly an advantage to have well fitting spigots in these cases, but this was not an essential. Good and reliable joints could be made, providing the joint faces were true and only thin jointing material was used, and he considered that the cure of joint-failures generally lay in attention to these points.

No doubt, as the President remarked, a larger number of accidents occurred owing to water-hammer than was generally supposed. Usually, if water was standing in a vertical pipe with steam above it, this water could be drained off, thus lowering the level of the water in the vertical pipe without danger. What generally caused water-hammer was something of this kind:—Condensed water was standing in steam-pipes and when the drains were opened the surface of the water gradually fell until it was below the top of some horizontal length of pipe, or in some other way the surface of the water exposed to the steam was increased, when violent condensation of the water took place resulting in water-hammer. Water-hammer, as he understood it, was usually of the nature of the projection of a body of water or water-bullet along the steam-pipe or to and fro in it, and he would not expect that a safety-valve would be of the slightest use in preventing it as the water would pass the safety-valve just as if it were not there, unless it so happened that the valve were placed opposed to the direction in which the water was moving.

He considered that the only way to prevent water-hammer was to avoid accumulation of water in the pipes by the adoption of a system of continuous drainage, using steam-traps and suitable arrangements of drain-pipes. Steam-traps, however, required very careful supervision, and in its absence were liable to become deranged and inoperative.

The question of the most suitable expansion-joint for particular cases was important, and there was no doubt that different forms of joints would be best suited to different circumstances. As a rule, he preferred, in the design of steam-pipes, to avoid the introduction of any kind of expansion-joints, and would obtain sufficient flexibility to allow for expansion by adopting bends, angles and similar devices in the arrangement of the pipes. This plan, of course, was not universally applicable, and it was possible in the long vertical pipes which carried steam down coal-pits that practical difficulties would interfere with such a plan being adopted. It seemed to him that it would be possible to provide even for the large amount of vertical expansion which occurred in steam-pipes placed in shafts by running the pipes longitudinally for short distances on each side of the shaft and connecting them together by pipes passing round the sides of the shafts and thus obtain a flexible arrangement. He had met with many cases where ordinary gland expansion-joints were inoperative owing to the packing seizing and the two parts of the joint corroding together, and he had seen a number of cases about collieries where considerable leakage was taking place at steam-pipe joints owing to such sticking of gland expansion-joints. The conditions in which gland expansion-joints were used often militated against their being reliable and free in action, for in many cases the range of pipes was kept hot and full of steam for months together. Under these circumstances, little or no movement of the joints would take place and full opportunity would be given for sticking. His experience was that to ensure such joints acting it was usually necessary to sheath the joints with brass, to regularly renew the packing and also to see that the different sections of the pipes were definitely anchored. In some cases, large bellows expansion-joints appeared to give good results. He should anticipate that in these joints the flat sides would be liable to groove on the steam side owing to their movement and to give way without warning, but he had not met with any accident resulting from this action.

The vote of thanks was carried unanimously.

Mr. W. J. Orsman read the following paper on "Safety-explosives":—

SAFETY-EXPLOSIVES.

By WM. JAS. ORSMAN.

The Explosives in Coal-mines Order came into operation on January 1st, 1898, and with only 12 months' experience it might seem presumptuous on the writer's part to criticize the value of the different explosives now placed on the Permitted List. It must be borne in mind, however, that many of these explosives have been in active use in some districts for the last 10 years, and the following remarks are intended to deal with information obtained during that period of time.

The explosives now on the list are widely different in character and properties, and may be divided into the following classes:—(1) Those whose effects are due to rapid combustion; including the various forms of gunpowder, namely, argus powder, earthquake powder, elephant brand gunpowder, and oxalate blasting-powder. (2) Those in which explosion is in part due to detonation and in part to rapid combustion, such as carbo-gelatine, carbonite, kynite, and the various forms of gelignite. In these, the nitro-glycerine is detonated, and the heat and flame formed cause rapid ignition of the carbonaceous matter with the nitrate of potassium. (3) Those due solely to detonation, such as ammonite, amvis, bellite, dahmenite, electronite, faversham powder, pembrite, roburite, and westfalite.

The tests at present employed to determine the safety-value of an explosive depend on the inability of a certain weight, when tamped with a certain amount of stemming in a steel cannon of given dimensions, to ignite an explosive mixture of air and ordinary coal-gas of known proportions. The question, to the writer's mind, is, ought mining engineers who are responsible for life and property, to be satisfied with this one factor of safety? Looking at the properties of some of the explosives represented, and the records of their past history, the writer thinks that there are other considerations to be included.

Putting aside the question of the effect of firing shots in a mine, which in itself is a most important study, the author proposes to deal with another point which has not been considered in drawing up the present list, namely, the question of handling explosives, and hopes to show that the present Permitted List could easily be supplemented by another list, called Permitted Safety-explosives.

A shot-firer has to be taught his work, and in the oft-times cramped space at his disposal and limited amount of light, safety in handling is a most important factor. One has only to look at the official reports for the past few years to note accidents arising from very ordinary and simple causes, for instance, dropping a lighted match or candle or heated snuff from a candle on to gunpowder; premature explosion by a spark, produced by a pick or falling bodies; incautious thawing of compounds that easily become frozen or hard, such as nitro-glycerine compounds, gelignite, carbonite, carbo-gelatine, etc. The list might now be divided into the following classes:—(1) Those compounds that are very easily exploded by sparks, by too hard ramming, or other form of concussion, such as nitro-glycerine compounds and various forms of gunpowder. (2) Those compounds which cannot be exploded by friction, concussion, sparks, or any other form of heat, and which can only be exploded by detonation.

Of all known explosives used in coal-mining, by far the worst offender in the past, so far as published results show, is ordinary blasting-powder. This may be accounted for by its having the property of being easily ignited at a low temperature, being a slow-burning mixture, and that over 50 per cent. of the products of combustion is incandescent solid matter.

Table I., compiled from the reports of H.M. inspectors of mines for the last 10 years, will give some idea of the large number of accidents due to handling explosives. Table II. contains details of the accidents for the various mines-inspection districts.

TABLE I.—ACCIDENTS FROM HANDLING EXPLOSIVES IN COAL-MINES, FROM 1887 TO 1897.

Name of Explosive.	No. of Accidents.	No. of Killed.	No. of Injured.
Gunpowder	1,276	180	1,324
Nitro-glycerine compounds—			
Dynamite, etc.	67	29	76
Carbonite	54	14	46
	— 121	— 43	— 122
Nitrate-of-ammonium compounds ...	45	11	41
Other high explosives	5	1	7
Detonators	37	0	38
Uncertain or unknown	289	15	294
Totals	1,773	250	1,826

TABLE II.—ACCIDENTS FROM HANDLING EXPLOSIVES IN COAL-MINES, FROM 1887 TO 1897.

Mines-inspection District.	Gunpowder.			Nitro-glycerine Compounds.			Nitrate-of-Ammonium Compounds.			Other High Explosives.			Detonators.			Uncertain or Unknown.			Totals.		
	No. of Accidents.	No. of Killed.	No. of Injured.	No. of Accidents	No. of Killed.	No. of Injured.	No. of Accidents.	No. of Killed.	No. of Injured.	No. of Accidents.	No. of Killed.	No. of Injured.	No. of Accidents.	No. of Killed.	No. of Injured.	No. of Accidents.	No. of Killed.	No. of Injured.	No. of Accidents.	No. of Killed.	No. of Injured.
East Scotland	190	21	199	21	6	20	—	—	—	—	—	—	6	0	6	8	4	4	225	34	229
West Scotland	147	26	152	8	7	6	—	—	—	—	—	—	4	0	4	37	5	33	196	38	195
Newcastle-upon-Tyne ...	273	22	286	6	3	6	3	1	2	—	—	—	9	0	9	18	3	19	309	29	322
Durham	177	20	160	10	3	8	4	1	3	—	—	—	1	0	1	114	0	114	306	24	286
Yorkshire	21	9	13	4	1	4	2	2	2	—	—	—	—	—	—	11	1	14	38	13	33
Manchester	44	9	53	4	0	9	2	0	2	—	—	—	3	0	3	—	—	—	53	9	67
Liverpool	14	6	13	7	0	7	8	5	4	—	—	—	2	0	2	—	—	—	31	11	26
Midland	101	7	102	8	0	9	12	0	13	1	0	2	7	0	8	32	0	35	161	7	169
North Staffordshire	62	13	64	9	2	11	10	1	11	1	1	0	1	0	1	13	0	14	96	17	101
South Staffordshire	24	15	25	—	—	—	—	—	—	—	—	—	—	—	—	11	0	11	35	15	36
South-western	81	8	97	6	5	9	3	1	2	1	0	1	—	—	—	12	0	16	103	14	125
South Wales	142	21	160	38	16	33	1	0	2	2	0	4	4	0	4	33	2	34	220	39	237
Totals	1,276	180	1,324	121	43	122	45	11	41	5	1	7	37	0	38	289	15	294	1,773	250	1,826

Table II. refers only to accidents due to incautious handling, and not from any explosion of gas or dust. Tables III. and IV. show the number of accidents and deaths caused by different explosives setting fire to gas or coal-dust and air in the pit during the past 10 years.

TABLE III.—ACCIDENTS FROM EXPLOSIONS OF GAS OR COAL-DUST IN COAL-MINES CAUSED BY EXPLOSIVES, FROM 1887 TO 1897.

Name of Explosive.	No. of Accidents.	No. of Deaths.
Gunpowder	21	256
Tape-fuze	7	66
Nitro-glycerine explosives	4	345
Nitrate-of-ammonium explosives	Nil.	Nil.
Other high explosives	1	1
Uncertain or unknown	1	1
Totals	34	669

TABLE IV.—ACCIDENTS FROM EXPLOSIONS OF GAS OR COAL-DUST IN COAL-MINES CAUSED BY EXPLOSIVES, FROM 1887 TO 1897.

Mines-inspection District.	Gun-powder.		Tape Fuze.		Nitro-glycerine Explosives.		Nitrate-of-Ammonium Explosives.		Other High Explosives.		Uncertain or Unknown.		Totals.	
	No. of Accidents.	No. of Deaths.	No. of Accidents.	No. of Deaths.	No. of Accidents.	No. of Deaths.	No. of Accidents.	No. of Deaths.	No. of Accidents.	No. of Deaths.	No. of Accidents.	No. of Deaths.	No. of Accidents.	No. of Deaths.
East Scotland	2	74	—	—	—	—	—	—	—	—	—	—	2	74
West Scotland	2	2	1	1	—	—	—	—	—	—	—	—	3	3
Newcastle-upon-Tyne	5	42	—	—	1	6	—	—	—	—	1	1	7	49
Durham	1	20	—	—	—	—	—	—	—	—	—	—	1	20
Yorkshire	1	2	2	5	—	—	—	—	—	—	—	—	3	7
Manchester	2	3	—	—	—	—	—	—	—	—	—	—	2	3
Liverpool	2	6	2	2	—	—	—	—	—	—	—	—	4	8
Midlands	1	7	—	—	—	—	—	—	—	—	—	—	1	7
North Staffordshire	—	—	1	1	1	10	—	—	1	1	—	—	3	12
South Staffordshire	—	—	—	—	—	—	—	—	—	—	—	—	—	—
South-western	3	11	—	—	—	—	—	—	—	—	—	—	3	11
South Wales	2	89	1	57	2	329	—	—	—	—	—	—	5	475
Totals	21	256	7	66	4	345	Nil.	Nil.	1	1	1	1	34	669

The members may here note the remarkable fact that during the last 10 years not a single life has been lost from the ignition of gas or dust in a pit that could be traced to a nitrate-of-ammonium explosive *per se*. Where accidents have occurred when using these explosives they have been found to be due to the use of tape-fuze, and these circumstances show the advisability of only firing by electricity.

Attempts have been made to improve the older forms of blasting-powder in several ways; for instance, by more careful mixing and incorporation of the ingredients, by reducing the amount of sulphur, and by the addition of foreign substances, such as bicarbonate of soda or oxalate of ammonia, which do not add to the explosive force, but reduce the temperature, or tone down the flame on account of steam liberated (due to water of crystallization or to the decomposition of the salt itself). The decomposition of certain salts, however, such as oxalate of ammonia, may be attended with very unpleasant results, the fumes being detrimental to the health of the miners, and possibly producing sore throat. In well-ventilated mines this inconvenience may be reduced to a certain extent, but in confined places serious results might follow.

The addition of foreign salts to the gunpowder is made either by mixing direct with the ingredients of the powder, or as a plug at the end of the cartridge. The latter method is simply a form of safety-tamping, which at any time could be removed from the cartridge, and its use is most unadvisable.

The new gunpowders which have passed the test are only pronounced safe because, when fired out of a cannon, they fail to fire a mixture of coal-gas and air ; but supposing a cartridge should be accidentally fired on a dusty road, it might happen that a violent explosion would be started. All forms of gunpowder easily ignite coal-dust, and a most instructive experiment is to place a cartridge of gunpowder in an exposed place at the surface, and cover it with a sack of coal-dust. On firing the powder, the coal-dust is scattered in all directions, and bursts into a large volume of flame, every particle of coal-dust projected into the air being consumed. This might very easily occur accidentally in a dusty mine, and, without any gas being present, the flame would probably spread in all directions. With detonating-explosives of the nitroglycerine class this may, and in fact has occurred, but with nitrate-of-ammonium explosives not even a flame or spark is seen.

There is another important point which occasionally crops up, and that is the liability of an unexploded cartridge left in a mine, and mixed up with the coal, to find its way on to a boiler-fire. With nitro-glycerine compounds and gunpowder, serious results might follow, but with nitrate-of-ammonium compounds there is absolute safety. Cartridges of the latter can only be exploded by means of a detonator, and cartridges thrown on to a fire burn away slowly without any sign of explosion.

Owing to the varied nature of the explosives now in general use, it is difficult to draw up any set of rules to be followed in firing shots that shall be applicable to all mines. There is, however, one matter which demands most serious consideration, when firing several cartridges placed end to end, by means of a detonator. The writer has several times found that the practice is, when, say, two cartridges are fired together, to put the detonator in the middle, so as to come between the two cartridges; or when, say, three cartridges are used, to put the detonator in the middle cartridge. This method has nothing to recommend it, being absolutely wrong in practice, and it may lead to serious results. When explosives are fired with detonators the explosion is started and carried through the whole length of the cartridge, not on account of heat developed, but by a detonating-wave, the vibrations of which have enormous velocity, and if the rhythm be interrupted, detonation ceases. For this reason, it is absolutely necessary that detonation should start from one end, and proceed uninterruptedly to the other. The detonator should be placed at the end nearest the mouth of the bore-hole. The latter position is necessary for the following reasons: If a cartridge or part of a cartridge fails to explode, the impact of explosion at the front will simply crush the unexploded part into a solid block at the back of the hole, where it can be easily found and recovered. If, however, the detonator is at the back of the hole, any unexploded portion will be sent flying in all directions with the coal, and mixed with the coal will be small pieces that will easily escape detection. Further, if the coal is not brought down, and a blown-out shot produced, then any unexploded portions will be projected over the surface of coal at the sides of the bore-hole at an enormous velocity, and the friction set up may cause the explosive to ignite, and so set the coal on fire. With the detonator placed at the end of the cartridge, nearest the mouth of the bore-hole, such a circumstance is impossible. Investigation of a large number of cases where difficulties have arisen has shown that these have been almost invariably due to wrong methods in charging the shot-hole.

The PRESIDENT (Mr. J. A. Longden) suggested to Mr. Orsman that he should place the tonnage opposite each district in the tables. For instance, there was a great difference between districts like South Wales and Staffordshire, and the tonnage would afford a kind of comparison between one district and another. At the pits under his charge, they had made extensive experiments with explosives: they were using amvis entirely, and it was more closely similar in its action in the working of coal to gunpowder than to anything else. There was no doubt whatever that there was a vast difference between one coal-dust and another. He had given evidence before the Coal-dust Commission on this point especially, and from the experiments carried out by the

Committee of the Chesterfield and Midland Counties Institution of Engineers some years ago he was astonished to find the great difference of inflammability between one dust and another.

Mr. W. N. ATKINSON (H.M. Inspector of Mines, North Staffordshire) said that there was a very considerable difference in the actual safety of the explosives on the Permitted List. It was wellknown that gelignite would ignite both coal-dust and fire-damp in the case of a blown-out shot, but the same could not be said of some of the other explosives which were originally known as safety-explosives. There was a great difference between the relative safety of such explosives as carbonite, roburite, and others, and such an explosive as gelignite. The more recent additions to the Permitted List seemed to him to be going in the direction of further reduction in the safety of the explosives. Some coal-dusts, no doubt, were more easily inflammable than others, but the important point was whether all coal-dusts were not sufficiently inflammable under certain conditions as to be dangerous, and as far as he knew, or could judge from experiments, it had not been shown that any coal-dust was incapable of causing explosion. The colliery-owners and miners of South Wales, where anthracite was worked, asserted, before the Explosives Order was promulgated, that such dust was not dangerous. Owing to this statement, anthracite coal-dust was tested at the Woolwich Station, and was proved to be as dangerous as any other coal-dust.

Prof. LOUIS (Newcastle-upon-Tyne) pointed out that, whether one was prepared to agree or not with Mr. Orsman's conclusions, the data were by no means, to his mind, satisfactory. He referred more particularly to Table I., which showed, as the result of handling explosives, 1,276 accidents from gunpowder, 121 from nitro-glycerine compounds, 45 from nitrate-of-ammonium compounds, and so on. But it was, he maintained, a fact that there had been at least 10 tons of gunpowder used for every ton of high explosives. If that were so, one would naturally expect the proportion of deaths which Mr. Orsman had placed before them, and the ratio of 10 to 1 was only what they might expect. It appeared to him that Mr. Orsman had not made out his case, so far as the danger attending the use of gunpowder was concerned. Unless, however, they had all the data, namely, the quantity of each explosive used and the number of explosions per ton of explosive used, then they had insufficient data to go upon, and would be apt to draw a wrong conclusion. He did not think that the members were warranted from the facts before them in accepting the statement that gunpowder was more dangerous than other explosives. Those who had had practical experience with gunpowder would, he thought, conclude that it was not dangerous to handle in the pit. Gunpowder, moreover, had been used for many years, and miners were probably better able to cope with the dangers connected with its use than with that of any of the other explosives. Gunpowder would keep its quality unimpaired for years: could they say the same for these other explosives? He ventured to think that when old stores of these new explosives were used they would also have other difficulties to face. Until these points were settled:—First, the ratio between the quantity of gunpowder used and that of the other explosives, and the numbers of accidents arising from the same; and, secondly, the manner in which the new explosives behaved after having been stored for some length of time, they could not pronounce decisively on the matter.

Mr. E. B. **Wain** (Chatterley-Whitfield collieries) remarked that, without saying a word in favour of blasting-powder, he had no hesitation in stating that there had been no efficient substitute provided by any maker of explosives.

Mr. G. A. **Mitcheson** (Longton) asked whether the majority of explosions did not occur through handling the detonator rather than the explosive. That was, he thought, especially the case so far as ammonium-nitrate explosives were concerned. There was more risk in the use of nitroglycerine compounds, but in his opinion the principal danger occurred with the detonator, especially when it was remembered what risk was run of detonators getting lost and being mixed with the coal.

Mr. **John Simpson** (Newcastle-upon-Tyne) said that he could fully bear out by his experience Prof. Louis' remarks as to the safety of gunpowder. During the last 10 years, he had fired at least 400 shots per day at his colliery, and had used nothing but gunpowder until the beginning of last year, while during 1898 they had had more accidents (chiefly from detonators) than during the 9 previous years.

Mr. M. **Walton Brown** (Newcastle-upon-Tyne) said that many colliers in using high explosives were in the habit, to avoid tying the detonator in the cartridge, of pushing in the detonator, bending the wire alongside the cartridge and placing the cartridge with the fuze at the far end of the hole. This was a dangerous system: in cases where electric firing was used the wires might become short-circuited, and instead of the fuze being detonated, the explosive might be ignited and burn without explosion. He considered that nitro-glycerine explosives should be divided into two classes, for dynamite should not be included with such explosives as carbonite. He thought that ammonium-nitrate explosives, after being stored for some time in a magazine, would become deteriorated and unsuitable for use as explosives.

Mr. J. C. CADMAN (Newcastle-under-Lyme) thought that more care should be taken in placing the detonator in position, and also as to the quality of the detonator. He had had several mishaps from the detonators being deficient in strength. It seemed to him to be dangerous to allow gunpowder of any description to be used in dusty mines. The members were indebted to Mr. Orsman for his paper, and he had pleasure in moving a vote of thanks to him.

The PRESIDENT said that the danger arising from the handling of detonators was strikingly illustrated in the case of a workman at one of his pits. He had stored up several sovereigns in his detonator-box, as he "had no other place to keep them." He had pleasure in seconding the vote of thanks, which was cordially approved.

Mr. DONALD M. D. STUART (Bristol) wrote that although Mr. Orsman entitled his subject "Safety-explosives," or "Explosives now . on the Permitted List," he devoted a considerable part of his paper to an explosive that was not on the list. The object of the paper was stated in the following terms:—(*a*) "To criticize the value of the different explosives now placed on the Permitted List." (*b*) To deal with "many of these explosives" that "have been in active use . . . for the last 10 years." (*c*) To look "at the properties of some of the explosives . . . and the records of their past history." (*d*) "Putting aside the question of the effect of firing shots in a mine . . . to deal with another point . . . namely, the question of handling explosives." In a few words, to deal with explosives on the Permitted List that had been in active use for the last 10 years; and, excluding the effects of firing shots in a mine, to limit attention to the question of handling explosives. Mr. Orsman apparently immediately forgot the question and limitations to which he had invited the attention of the members, and embarked upon another subject, namely, explosives not on the Permitted List, explosives not used for the last 10 years, and the effects of shot-firing in mines. This change of position led to a confusion of thought, which exhibited itself in Mr. Orsman's treatment of the question to which he diverted his paper. The new subject was non-permitted ordinary blasting-powder, permitted gunpowders introduced within recent months (consequently of a short history, clearly too slender for discussion) and the alleged 10 years of disasters with ordinary blasting-powder.

The three permitted gunpowders—argus, earthquake and elephant—were specified; but evidently Mr. Orsman felt the absence of evidence regarding them, so he perfected the departure from the object he propounded by drawing away attention to "ordinary blasting-powder," to supply a gunpowder of 10 years' history, and link in alleged disastrous effects of shot-firing by its employment. Mr. Orsman then painted a picture of ordinary blasting-powder clothed with 10 years' history of alleged disaster and death, and wrapped it round the permitted gunpowders, admittedly to submerge their distinctness of identity and difference in nature.

The historical distinction between gunpowder that had been in active use for 10 years, and gunpowders of less than as many months' experience, could not be confused. The differences between gunpowder of one composition and manufacture, and gunpowders of essentially different compositions and manufacture, admitted of no difficulty of comprehension. The distinction between gunpowder which when fired in explosive gas ignited it, and gunpowders which when fired in identical conditions would not ignite the gas, was an obvious fact. By virtue of this fact all Permitted Explosives enjoy their position in the list. The permitted gunpowders of recent discovery, of new compositions and manufacture, and safe for firing in explosive gas, therefore could not be confused with ordinary blasting-powder.

The risks of ordinary blasting-powder have been greatly exaggerated, and the disasters due to it magnified and multiplied without regard for accuracy. Mr. Orsman furnishes Table I. purporting to give the number of accidents and number of persons killed or injured, from 1887 to 1897, by handling explosives, upon the authority of the annual reports of H.M. inspectors of mines. These reports record only the fatal accidents up to 1895, and subsequently omit the explosives used in the non-fatal accidents. The figures of non-fatal accidents, persons injured, and explosives used in this table, are not given in the reports to which Mr. Orsman refers; and appeared to be of anonymous origin. They could not be considered as of any value unless Mr. Orsman furnished an authority for them. The number of deaths also appeared to be incorrect, as indicated by the following comparative statement;—

PERIOD FROM 1887 TO 1897.

Name of Explosive.	Mr. Orsman in Table I. Deaths.		Records in the Annual Reports of H.M. Inspectors of Mines. Deaths.
Gunpowder	180	...	150
Nitro-glycerine explosives ...	43	...	35
Nitrate-of-ammonium explosives	11	...	10
Other high explosives	1	...	1
Uncertain	15	...	10
Totals	250	...	206

This statement of fact conveys the impression that gunpowder had been subjected to unfair treatment and disparaged by incorrect figures. Mr. Orsman's Table I., and the depreciation of blasting-powder built upon it, could not therefore carry any weight to persons responsible for the safety of coal-mines.

Table IV. purported to tabulate explosions of gas or coal-dust caused by explosives, also upon the authority of the reports of H.M. inspectors of mines. An examination of this table with the reports indicated that Mr. Orsman had charged gunpowder not only with explosions believed to have been due to it, but also with explosions where there was no evidence that a shot was fired, and explosions officially recorded to have been caused by other means. He had also debited tape-fuze and nitro-glycerine explosives with explosions caused by shots officially recorded to have been charged with nitrate-of-ammonium explosives; and by these methods Mr. Orsman invited the members to believe that nitrate-of-ammonium explosives had not caused one explosion, but that gunpowder was the "worst offender." A few extracts from the table would illustrate the nature of Mr. Orsman's evidence in support of the conclusions which he asked the members to accept. The following are a few examples from Table IV. :—

	Gunpowder.		
Mines-inspection District.	Number of Accidents.		Number of Deaths.
East Scotland	2	...	74
Newcastle-upon-Tyne	5	...	42
Manchester	2	...	3
South Wales	2	...	89

In the South Wales district, 87 of the deaths were caused by the Morfa colliery-explosion, of which the report states :—"It should be mentioned that there was no positive evidence of a shot having been fired at or about the time of the explosion."*

In the Manchester district, 2 of the 3 deaths arose from a shot charged with securite, one of the nitrate-of-ammonium explosives.

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* *Report of an Explosion at the Morfa Colliery*, page 19.

In the Newcastle district, 30 of the 42 deaths happened in the St. Helen's colliery-explosion, where no doubt a gunpowder shot had been fired, but the explosion did not occur for 12 hours afterwards, and was due to reversal of ventilation. The report says:—"It was probable that the change in the ventilation and the consequential temporary lying dead of the air caused gas to accumulate in the workings in Hoggs brow in dangerous quantity. That on the ventilation (circulation) being restored the effect was to drive this accumulation rendered explosive on the infusion of air on the fire and there to be ignited. It seems in support of such a theory that the fire burned for 12 hours without causing any damage beyond its immediate ambit, and the explosion followed immediately after the change of air."*

In the East Scotland district, one of the explosions causing 1 death was in a shale-mine, and due to "a shot;" the explosive in the shot-hole not being recorded. The other explosion at Udston colliery, with 73 deaths, was reported upon as follows:—"On various of the bodies found in the pit there were matches ignited and unignited, tobacco, pipes, lamp-keys and nails,"† and the conclusion arrived at was, "that it was primarily caused by the ignition of some fire-damp at an open light, or at a match, or by being drawn through the gauze of a Scotch safety-lamp."‡

Eliminating the explosions not caused by gunpowder shots, or in which there was no evidence of such a shot, Mr. Orsman's total of 256 deaths caused by gunpowder falls to 61.

The evidence of explosions charged to tape-fuze was equally unsatisfactory, as the explosions were caused by shots charged with the nitrate-of-ammonium explosives—ammonite and roburite. Mr. Orsman's contention demanded the presence of 5 to 6 per cent. of gas at the mouth of the shot when the fuze was ignited, and the violation of a specific rule by the firemen in not discovering gas which must have been conspicuously burning in their lamps; a violation which invited suffering—probably death. With the exception of possibly 3 deaths, H.M. inspectors of mines defend the firemen from this charge. They stated their view that at Hebburn, Thorncliffe and Tylorstown colliery-explosions gas was concealed in the strata, and liberated into the atmosphere by the explosion of the charge; at which time the tape-fuze had burned out in the detonator. The products of the explosives remained the only source of heat to ignite the gas. These facts appeared to be reasonably conclusive evidence that the ammonite and roburite caused the explosions. This conclusion received some confirmation from the occurrence of a "serious ignition of fire-damp" causing a fire in the Midland mines-inspection district, reported by Mr. A. H. Stokes, H.M. inspector of mines. Mr. Stokes stated that tape-fuze did not ignite the gas, but that the gas was ignited by the roburite in the shot, and the ignition would have occurred if the charge had been electrically fired.[*]

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* *Report of the Explosion at St. Helen's Colliery*, page 6.

† *Report of the Explosion at Udston Colliery*, page 14. ‡ *Ibid.*, page 21

Under explosions by shots of nitro-glycerine explosives, Mr. Orsman placed the Hebburn colliery-explosion, which was caused by a charge of roburite, detonated by a gelignite-primer.

The foregoing examination of Mr. Orsman's figures appeared adequate to illustrate their untrustworthiness. Table III. and the records in the reports of H.M. inspectors of mines could now be placed in juxtaposition, namely:—

EXPLOSIONS FROM 1887 TO 1897.

Name of Explosive.	Mr. Orsman in Table IV. Deaths.	Records in the Annual Reports of H.M. Inspectors of Mines. Deaths.
Gunpowder	256	61
Tape-fuze	66	3
Nitro-glycerine explosives	345	339
Nitrate-of-ammonium explosives	Nil.	67
Other high explosives	1	2
Doubtful	1	88
Other causes	Nil.	30
Totals	669	590

The foregoing facts indicated Mr. Orsman's employment of the annual reports of H.M. inspectors of mines, to give authority to figures and conclusions which they did not contain; to enforce his statement that gunpowder was the worst offender, and that there had not been an explosion of gas or coal-dust with a nitrate-of-ammonium explosive. The reports indicated that ordinary blasting-powder held the best record (although it was used in at least 90 per cent. of the shots fired) with 61 deaths; nitrate-of-ammonium explosives coming second with 67 deaths, and nitro-glycerine substances third with 339 deaths.

Notwithstanding the superior record of ordinary blasting-powder, compared with safety-explosives, it had, like the nitrate-of-ammonium and nitro-glycerine explosives, caused disasters that every member desired to avoid; and the new permitted gunpowders were introduced on evidence that promised a considerable realization of this desire. It was, then, obviously unfair to foist 10 years' history of disasters with ordinary blasting-powder, upon the permitted gunpowders; disasters which occurred where the permitted gunpowders were never used, and, in fact, many years before they were made or even discovered.

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[*] *Report, Midland District*, 1889, page 8; and *First Report of the Royal Commission on Coal-dust*, questions 3067, and 3105 to 3109.

Some other features of Mr. Orsman's paper called for notice, where it was stated that the permitted gunpowders were easily exploded by sparks and ramming, while nitrate-of-ammonium explosives could not be exploded by friction, concussion, sparks, or any form of heat. Mr. Orsman would have been more correct had he said: two of the permitted gunpowders were difficult to ignite by spark, or flame, or friction, all were enclosed in spark and friction-proof cartridge-cases, and could not be exploded in charging or by ramming; while nitrate-of-ammonium and nitro-glycerine explosives had been frequently exploded in charging and ramming the shots.

Mr. Orsman also suggested that the oxalate of ammonium in the elephant cartridge did not add to the power of the elephant gunpowder, and caused injurious fumes. The contrary was the case, as the oxalate of ammonium added sensibly to the power, and many tons of the cartridges had been used in mines without producing fumes or one single complaint. The argus and earthquake powders had yielded no irritating or discomforting fumes, even in blown-out shots. The smoke yielded by all three powders was certainly not more obnoxious than the smoke of the nitrate-of-ammonium explosives; consequently Mr. Orsman's statement as to fumes, like his observation that "50 per cent. of the products of combustion is incandescent solid matter," was pure imagination.

It appeared unnecessary to follow Mr. Orsman's further observations as to the dangers of ordinary blasting-powder, since they could find no place in the minds of engineers acquainted with the working and management of coal-mines. It might, however, be advisable to refer to his depreciation of the Woolwich test. Mr. Orsman suggests that "mining engineers, who are responsible for life and property," should not place reliance upon the Home Office test as a means for selecting explosives for dangerous mines. The tests were decided upon by the Home Office Testing Committee, which comprized four of H M. inspectors of mines, three of H.M. inspectors of explosives, and the chairman. The test, as as is wellknown, consisted in firing charges of the explosives as blown-out shots into a highly explosive mixture of coal-gas and air. Mr. Orsman apparently forgot that before the new gunpowders were discovered, he addressed the members upon the question of tests, and said:—"It then becomes a question what limit must be taken to ensure perfect safety when firing in fiery or dusty mines. The greatest danger that can be apprehended is the possibility of a blown-out shot into an explosive mixture of air and coal-gas."* The committee's test, as will be seen, embodies Mr. Orsman's "greatest danger that can be apprehended" "in fiery and dusty mines;" and the permitted gunpowders having passed this test, they, according to the standard which Mr. Orsman invited the members to accept, "ensure perfect safety" in such mines.

Mr. W. J. ORSMAN, replying to the discussion, said that the principal point raised had been as to the correctness of his tables—whether they could be relied upon to give correct information as to the comparative loss of life arising from the use of explosives. He would ask one question: Did Prof. Louis suggest that the quantity of gunpowder used in the Newcastle-upon-Tyne mines-inspection district was 100 times greater than of permitted explosives? As regarded the Manchester mines-inspection district he thought he was correct in stating that the quantity of permitted explosives used was 10 times that of gunpowder; in fact, about the Wigan district it was rather a difficult matter to find places where gunpowder had been used during the last 10 years. The members had before them a very significant fact; in the Scotch and South Wales districts, which were always claimed as being the safest in the country, and where candles were used, the greatest number of deaths and explosions occurred. He would also refer to the fact, which had already been noticed, that a large number of explosions took place in the use of the new explosives, owing to the detonator. Most of the cases had occurred because the shot had been placed in the hole ready for firing, and the workman at the end of the cable had fired the shot before the other workman had got away. Detonators always required a certain amount of care in their use, and workmen did not recognize their extreme danger. Having examined a large number of coal-dusts he had found that they were all more or less easily ignited by gunpowder, and the experiment had been alluded to in his paper. He asserted that they could not find any coal-dust that could not be ignited by some kind of gunpowder, except when the dust was mixed with a large percentage of dirt.

With regard to the points raised by Mr. D. M. Stuart, it was not right for him to state that the figures of non-fatal accidents in handling were not given by H.M. inspectors of mines. The figures recorded in his paper were taken from these reports, and can be verified by anyone who chooses to consult them; and when the cause of explosion causing the accident is omitted by H.M. inspector of mines it is entered in Table C as uncertain or unknown. The number of deaths given in Table I. is accurate, the figures presented by Mr. Stuart being taken, not from the reports of H.M. inspectors of mines, but from his own report to the Gunpowder Trades Association, which is in many respects inaccurate. This is also the case with regard to the explosions due to tape-fuze and nitro-glycerine explosives, as it is not H.M. inspectors of mines, but Mr. Stuart, who has "officially" recorded them as caused by nitrate-of-ammonia explosives.

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* *Trans. Inst. M.E.*, vol. iii., page 96.

In his examples from Table IV. as to the Morfa and St. Helens colliery explosions, it is rather late in the day for Mr. Stuart to dispute that they were caused by gunpowder shots, inasmuch as he tabulates them under gunpowder in his own reports and has throughout treated them as such.

Respecting the accident in the Manchester district at Ashton Moss colliery, Mr. Dickinson reported as follows:—"The explosive ordered to be used was securite, but from the indications left after the shot, powder was apparently used instead."* The lighting was by fuze, ignited by a wire heated through a small hole in the shot-firing lamp. Securite, by the way, was not a nitrate-of-ammonia but a nitrate-of-potash explosive, and had never been included in the Permitted List.

As to the St. Helens colliery explosion, Mr. Stuart quoted one part of the report of H.M. inspector of mines, but omitted the substance which gives the true cause of the explosion. Mr. Willis stated that "cartridges of compressed gunpowder was the explosive used, and was supplied by the owners. . . . Fire-damp issuing near the face of Hogg's Brow appears to have been ignited at the point of issue by the flame of the shot, and continued burning, eventually setting fire to the coal and brattice."†

In the East Scotland district, reference as to the Udston accident can be made to Mr. Morris' report, where we find it stated that "there had probably been a very small quantity of gas in the place when the explosion began, and a shot, fired surreptitiously without an examination, fired the gas."‡

The other explosion in this district was not in the shale mine as Mr. Stuart suggested, but at Darngavil colliery in 1897, of which Mr. J. B.

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* *Report*, page 10. † *Report*, page 7. ‡ *Report*, 1887, page 45.

Atkinson writes, " A suggestion to break up the gas by firing a charge of gunpowder appears to have been made by one of the deceased men and was agreed to by the under-manager, who nearly lost his life in the explosion that followed."*

Mr. Stuart's last comparative table was most misleading, as the figures in the columns under his (Mr. Orsman's) name were taken from the Reports of H.M. inspectors of mines, while those headed " Records in the Annual Reports of H.M. Inspectors of Mines " were simply and solely Mr. Stuart's own, for which no one but himself can be held responsible.

In his last comparative table Mr. Stuart demonstrated, in his own way, the superior record of ordinary blasting-powder, and then extols the virtues of the Woolwich tests because they admit certain new gunpowders. He forgot to mention that these experiments have absolutely excluded ordinary blasting-powder, which he had just before said was not at all dangerous. The new gunpowders were simply modifications of a very dangerous mining explosive, and nothing that Mr. Stuart can say would shake what the inspectors in charge of the tests have said themselves, viz., that admission to the Permitted List only implies greater safety than appertains to explosives which are excluded from the list. The tests show that the new gunpowders, used in certain quantities, with certain precautions, are comparatively safer than the old gunpowders. Only practical use can decide whether they are as much safer as the nitrate-of-ammonia explosives have been proved to be by 10 years' continuous experience. His (Mr. Orsman's) tests, carried out in various ways, proved that gunpowder in any form when fired in the presence of coal-dust was infinitely more dangerous than any nitrate-of-ammonia explosive ever could be.

The SECRETARY read the following paper by Mr. Arthur P. Wilson on " Sulphur-mines in the South of Spain " :—

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* *Report*, page 8.

SULPHUR-MINES IN THE SOUTH OF SPAIN.

By ARTHUR P. WILSON.

It is wellknown that isolated deposits of native sulphur are found among the lesser spurs to the east of the Sierra Nevada, through a belt of country extending north-east from Gador in the province of Almeria to the town of Lorca in the province of Murcia, the physical as well as the geological conditions being very similar in each occurrence. A description, therefore, of one may be regarded as typical of the series.

The sulphur-mines of the Sierra Gador are situated about 11 miles (18 kilometres) north of the port of Almeria, the capital of the province of that name. At the time of the author's visit (1893), about half of this distance was covered by the government high-road from Almeria to Granada, and the other half by a very rough parish-road, but since then railway-communication has been established between Almeria and Gador, which town forms a station on the new line between Almeria and Linares. However, the cost of cartage was very cheap, the transport being effected in carts carrying loads of about 2 tons (2,000 kilogrammes) of stores and produce, and drawn by 4 or 5 mules. The carriage cost about 37 centimos of a peseta per Castilian quintal of 46 kilogrammes or about 8 pesetas (4s. 5d.) per metric ton.*

The formation in which the native sulphur occurs may be classed as Middle Eocene. It is composed of a succession of strata, which, in descending order, consist of :—

3. Coarse-grained limestone (foraminiferal).
2. Limestone-conglomerate.
1. Clay-marls.

The sulphur has permeated all these strata. In the limestone, it occurs in the joints and cavities, associated with gypsum in large masses; in the conglomerate, it occurs as a cement, binding the rounded pebbles together ; and, in the marls, the sulphur is present as innumerable veins crossing and re-crossing one another in all directions.

Between the marls and conglomerates in many places, there is found a band, varying in thickness, of almost pure sulphur, assaying probably

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* At the present rate of exchange of 36·25 pesetas per £1.

90 per cent. The sulphur in these instances presents a curious banded structure, the ordinary yellow sulphur alternating with narrow parallel ribbons of black sulphur.

The conglomerates are of varied form. In some places, they are composed of large rounded stones, and in others, of very small pebbles, while in some cases the pieces are angular, and constitute a distinct breccia.

The sulphur occurs generally in an opaque form, although occasionally crystals of translucent and almost transparent sulphur are found.

So far as proved, the sulphur-bearing zone at Gador measures about 1,300 feet (400 metres) in length by about 400 feet (120 metres) in width, and 160 feet (50 metres) in depth. This gives a mass of about 83,200,000 cubic feet (2,400,000 cubic metres) or say about 5,000,000 tons of sulphur-ore. The average sulphur contents may be reckoned at 15 per cent. so that the original amount of sulphur available may be taken at 750,000 tons. Deducting from this the sulphur already extracted,—estimated at 50,000 tons,—there remained at the time of the author's visit (1893) a balance of 700,000 tons of sulphur, estimated as available, though it would be prudent not to rely upon a larger amount than 400,000 tons, as then *in situ*.

The deposit has been attacked by a number of shafts and levels, but no uniform method or system of working has been followed. Until quite recently, the extraction was carried on by boys who carried the mineral in esparto baskets up steep gradients underground, having rough steps cut in the ground to give them foothold and enable them to bring their loads to the surface. Even now, this practice is not entirely discontinued, but a winding-shaft has been sunk, and an underground tramway laid, at least on one of the levels. The winding is carried on in a curious way. An endless wire rope is made to pass over pulleys at the surface, and thence to the drum of the engine, whence it passes to a pulley at the bottom of the shaft. There is no cage of any kind, but the *espuertas* or baskets are hung on to the travelling-rope by means of a short cord with which each basket is furnished, the end is given a half hitch round the wire rope, and it never seems to slip. The baskets are hung on, every 10 or 12 feet apart, and the rope travels at a slow speed. A man at the surface unslings them as they arrive, and the empty baskets are sent down in the same fashion.

The extraction of the sulphur from the raw ore is conducted in dome or beehive-shaped furnaces, built of common brick. There are 25 of these furnaces at Gador, 18 of which have a capacity of 180 tons (4,000 quintals), while 7 have a capacity of 240 tons (5,300 quintals).* The larger furnaces measure 16·4 feet (5 metres) in diameter, and 16·4 feet (5 metres) from the floor to the spring of the arch, with a total height of 24·6 feet (7·50 metres). They are said to last 7 years, without having to be rebuilt.

The rough mineral, as raised, is taken directly to the furnaces, while the fine ore is made plastic with water, formed into slabs and dried. In charging a furnace, the slabs are first built upon the floor of the furnace and the broken lump mineral is placed on the top of them. The charge is lighted from the top, and a current of air is drawn through the furnace by means of a fan. The draught is so regulated that only sufficient air is admitted to keep up the temperature necessary to fuse the sulphur. The fumes drawn off are passed into conduits, in which they deposit part of their sulphur-contents as flowers of sulphur, the remainder escaping as sulphurous anhydride by a chimney connected with these chambers. As soon as the required temperature has been attained, liquation commences, and the melted sulphur begins trickling down through the mass, and is tapped at the bottom of the furnace, and thence run into a quadrangular mould from which it is broken by picks, after it has cooled and solidified.

Each of the larger furnaces produces about 30 tons (660 quintals) of sulphur per charge, which is exactly 12½ per cent. of the charge, and the loss by combustion is said to be not more than 1½ per cent., though it is probable that this is sometimes greatly exceeded. The conduits and chambers are swept out from time to time, and contribute to the yield as flowers of sulphur.

The operations of charging, burning and discharging a furnace occupy from 12 to 15 days, and the work is so arranged that when certain furnaces are burning, another series is being discharged, and another refilled.

The annual production at Gador was about 4,500 tons of merchantable sulphur, at a cost, it is said, of 70 pesetas (£1 18s. 7d.) per ton f.o.b. at Almeria.

There is no reason to suppose that the limits of the deposit have been reached by any of the existing workings, in any direction, not even in depth.

It has been already stated that there is a great similarity in the occurrence of these deposits of native sulphur in Southern Spain, but as may be seen from the following section (Fig. 1) of the deposit at Lorca, the sulphur is there found cropping out along the face of an escarpment. A few prospecting adits have been driven along the face of the cliff, though the mineral is worked, not from the outcrop but by a vertical shaft.

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* One ton is equal to 22·081 Castilian quintals.

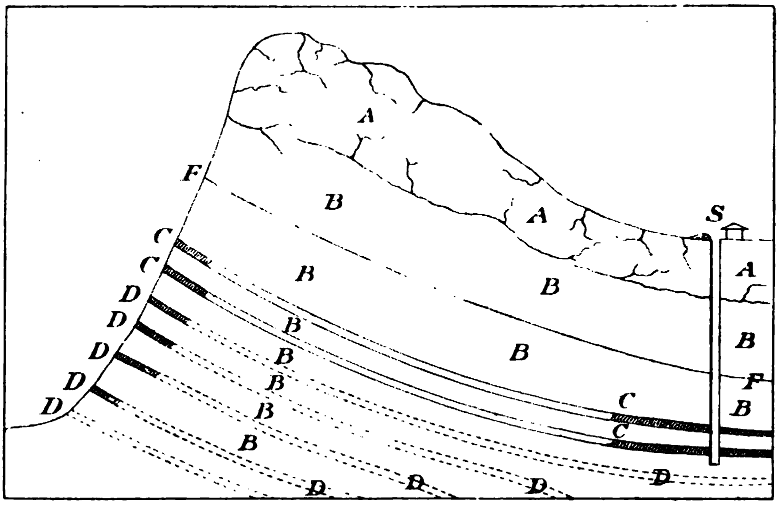

Fig. 1.—Vertical Section, showing Outcrop and Method of Working the Sulphur-mines, at Lorca, Southern Spain. *A*, is an Overlying Bed of Gypsum; *B*, Calcareous Marls and Clays; *C*, Beds of Sulphur, now being worked from Main Shaft; *D*, Beds of Sulphur, not yet worked; *F*, Ribbon of Sulphur; and *S*, Main Shaft.

The Secretary read the following paper by Mr. C. E. de Rance on "The Occurrence of Anyhydrite in the North of England," etc.

THE OCCURRENCE OF ANHYDRITE IN THE NORTH OF ENGLAND, ETC.

By C. E. De RANCE.

Through the courtesy of Mr. John Vivian, journals of certain borings in Furness have been furnished to the writer; and as they appear to be economically important and geologically interesting as regards the east and west of the North of England in the period immediately after the formation of the Coal-measures, the sections are herewith appended (see Appendix) and correlated with those on the north-east coast. But, first of all, some general observations may be of interest as regards the successive steps in our knowledge of this district.

In 1832, the Rev. Prof. Sedgwick* described the sequence of the St. Bees' series as follows, in descending order :—

1. Thick-bedded freestone of great thickness.

2. Sandy marls and slaty sandstone.

3. Unctuous red marl and strong gypsum-beds, which were worked, with a half-inch bed of carbonate of zinc, in all about 60 feet.

4. Grey, thin-bedded sandy marls, a few feet thick.

4. Yellow cellular Magnesian Limestone, often foliated, mixed and striated with red siliceous sandstone, containing jasper and chalcedony worked at Barrow and Preston How quarries.

5. Calcareous Magnesian Conglomerate.

6. Conglomerate, reddish in colour, containing rolled masses of limestone, mixed with hydrate of iron, beds 4 to 6, being about 60 feet in thickness.

7. The Whitehaven Sandstone, containing traces of *Equisetæ* and *Calamites*, but no other fossils. It is reddish in colour, and contains many small ferruginous nodules. Prof. Sedgwick compared it with the Red Sandstones lying between the Magnesian Limestone and true Coal-measures of Yorkshire, and apparently regarded it as true Coal-measures ; but in his sections he shows Nos. 1 and 2 beds as New Red Sandstone, Nos. 4 to 6 beds as a Magnesian Series, and No. 7 bed as Lower New Red Sandstone.

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* *Transactions of the Geological Society*, 1836, series 2, vol. iv., page 383.

Sir Roderick Murchison* in 1864 proposed that the St. Bees Sandstone, the Furness and Hawcoat Sandstones of North Lancashire, and the Corby Sandstone of the vale of Eden, all lying above the Magnesian Limestone, should be considered as part of the Permian system, forming a natural group, and as of older date than the New Red series. He refers these sandstones to the Upper Permian division, the limestones to the Middle Permian, and the breccia beneath to the Lower Permian, making it the equivalent of the Penrith Sandstone.

Dr. Nicholson in 1868† adopts Messrs. Murchison and Harkness' views, and compares the peculiar breccia, locally known as the "crab-rock," in the Duddon estuary, associated with the hæmatite-deposits, with the breccia forming the base of the Lower Permian series of the vale of Eden; and he points out that so far back as 1858 Prof. Phillips‡ suggested the hæmatite was of Permian age of infilling.

In 1873 Mr. Talbot Aveline§ gave a very interesting account of the Furness district of North Lancashire. He described the formations present in the following order:—

1. *Upper Permian Sandstone.*—Formerly held to be Bunter New Red. He quoted Messrs. Murchison, Harkness and Binney as to its "true geological horizon," and added that the two first-mentioned state "around Furness Abbey there are many fine exposures of the Upper Permian Sandstone, adding greatly to the beauty of the scenery, and at Hawcoat, about 1½ miles west of the noble ruin, the sandstones are largely worked, and are the materials which have been used in the construction of Furness Abbey."‖ These authors add that they are a deeper and duller red than the Penrith Sandstones, occasionally contain whitish and light-coloured layers, are associated with thin red shales or "wayboards," unknown in the lower series, and are much finer in grain.

2. *Magnesian Limestone*, worked at Stank as a building-stone, and containing a *Schizodus* and an *Arca.* These rest on Yoredale Shale, with plant-impressions. Mr. Aveline states that 63 feet of limestone is visible, and he considers this to be about the true thickness; furthermore, he considers the statement of its being 267 feet thick at Rampside, in a boring made by common boring-rods, as very improbable.

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* *Quarterly Journal of the Geological Society*, vol. xx., page 144.

† "An Essay on the Geology of Cumberland and Westmoreland."

‡ *Report of the British Association for the Advancement of Science*, 1858, "Notes and Abstracts," page 106.

§ *Memoir of the Geological Survey*, "Explanation of quarter sheet 91 N.W."

‖ *Quarterly Journal of the Geological Society*, vol. xx., page 159.

3. *Yoredale Limestone and Shale.*—The sinking at Stank proved 340 feet, consisting of dark argillaceous shale, ironstone-bands, inferior limestone and sandstone.

4. *Carboniferous Limestone.*—Greyish thick-bedded hard rock, exposed on the coast north of Aldingham.

No sections older than Glacial Drift being exposed in the island of Walney, Mr. Aveline states that "it was with great hesitation that the places wholly occupied by the Boulder Drift were coloured as Permian." Boring operations, since the publication of Mr. Aveline's "Explanation," have proved that this view was incorrect, the island being underlain by Keuper Marls, with thick beds of rock-salt, the channel between the island and the mainland being probably traversed by a north-westerly fault, with a downthrow to the west. The same phenomena occur at Preesall, east of Fleetwood, the Garstang Sandstones being there faulted against the saliferous marls by the same fault.

In 1881, Mr. T. V. Holmes,[*] in a paper "On the Permian, Triassic and Liassic Rocks of the Carlisle Basin," gives the following sequence:—

1.	Lower Lias, 200 feet.	Trias.
2.	Stanwix Marls.	
3.	Kirklinton Sandstone.	
4.	Upper Gypseous Shales, 700 feet.[†]	Permian.
5.	St. Bees Sandstone.	
6.	Lower Gypseous Shales. Penrith Sandstones, bright red.	

Mr. Holmes points out that the Kirklinton Sandstone rests unconformably on the St. Bees Sandstone, but "there is neither evidence or presumption of any kind in favour of the existence of unconformity between the St. Bees Sandstone and the Gypseous Shales." He favours a presumption of Permian affinity from the presence of gypsum, as it occurs below the St. Bees Sandstone. The Kirklinton Sandstone rests directly upon the St. Bees Sandstone east and north-east of Carlisle, and the thickness of the latter is estimated at 1,500 feet south-east of the city.

In 1887, Mr. H. B. Woodward reverts to the views of Prof. Sedgwick in 1832, and says [‡]:—"When we compare the succession of beds with that exhibited in other areas, there appears little doubt that the St. Bees Sandstone should be grouped as Bunter."

[*] *Quarterly Journal of the Geological Society*, vol. xxvii., page 286.

[†] Boring at Abbey Town.

[‡] *Geology of England and Wales*, second edition, page 213.

In 1893, the Director General of the Geological Survey, in his annual report to the Science and Art Department, says :—

> Mr. de Rance makes a special report upon the results of borings which have been in progress for some years past in the Fleetwood and Preesall district . . . made to explore the salt-deposits, which have shown that sandstone precisely similar to the Garstang Sandstone underlies the Keuper Marl of that area. The Garstang Sandstones have hitherto been classed as Permian, but there can now be no doubt that they should be regarded as Triassic. This change brings the red rocks of Lancashire into harmony with those of Cumberland, where the St. Bees Sandstone, formerly classed with the Permian, is now regarded by the Survey as Trias.

Anhydrite occurs in two forms, crystallized in rectangular prisms, and possesses double refraction, in the matrass it yields no water, and does not exfoliate before the blow-pipe like gypsum. The other variety known as vulpinite, from Vulpino, in Lombardy, where it is associated with limestone, is massive, and often contorted or reniform : from its resemblance to the convolutions of the intestines, the contorted type is known as *pierre des trippes*, and is found in the salt-mines of Wielitza and Bochnia, in Poland.

The following analyses give the constituents of the three types of sulphate of lime :—

	Eisleben.	Vulpino.	Typical Gypsum.
Sulphuric acid	56·28	58·00	46·0
Lime	41·48	41·70	33·0
Water	0·75	0·07	21·0
Silica	0·00	0·09	0·0
Analyst	Rose	Stromeyer	Buchholz

Anhydrite occurs in the Keuper New Red Marls at Cave Hill near Belfast, at Newark in Nottinghamshire, and Aston upon-Trent near Derby (pale blue granular). In the Bunter sandstones and Muschelkalk of Germany and the Alps, it is associated with gypsum and rock-salt. In the Zechstein of Germany, and in the Permians of Russia, it is similarly associated : it may, therefore, be regarded as occurring throughout the New Red and Permian series, as well as in the older rocks of the St. Gothard tunnel and of North America. It also occurs in the metalliferous veins of Andreasberg, in the Harz, in the Palæozoic slates :—galena occurring as a pseudomorph after it.

The vulpinite occurring in the salt-mines of Upper Austria and Salzburg, and at Vulpino, from the contained silica, takes a fine polish ; that from the latter locality is known to artists by the name of *marmo bardiglio di Bergamo*. They occur at the base of the Tuscan Liassic rocks, and consequently at about the same horizon as that at Newark, at the top of the Keuper Marls.

The Sperenberg boring (near Berlin) passed through 283 feet of anhydrite and gypsum, and no less than 3,769 feet of rock-salt. And Mr. von Dechen describes 1,017 feet of Zechstein gypsum and anhydrite measures, as overlying the rock-salt, at Artern, on the southern flank of the Harz. The Zechstein salt-mines of Stassfurt in Prussian Saxony have been followed to a depth of 1,300 feet, and at the bottom anhydrite and rock-salt occur in thin alternating layers.

At the Museum of Practical Geology are good specimens of anhydrite from the Keuper Marls of Newark-on-Trent, presented by Messrs. Cafferata & Co., in 1898, others from Derby and Nottingham and Salzburg, the latter being associated with rock-salt. In the case allocated to samples of boring-cores are specimens from a boring at the Warren Cement-works, at Hartlepool, presented by Dr. O. Treckmann, namely:—(1) Anhydrite, 267 feet in thickness, extending from 97 to 364 feet from the surface: (2) Magnesian Limestone, from 364 to 402 feet, of the latter there are two samples, and there can be no doubt that it is the true Zechstein Magnesian Limestone. This section is well in accord with those of Furness given in the Appendix. The two points are 87 miles apart in a west-north-westerly direction.*

Borings on the North Yorkshire and Durham Coasts.—The writer has published the details of a considerable number in the sixth, seventh and fifteenth reports of the Underground Water Committee of the British Association.† Further details were given in 1887 by Sir Lowthian Bell, "On the Manufacture of Salt near Middlesbrough"‡ in 1888, by Mr. W. J. Bird ;§ later in the same year by Mr. Wilson, and by Mr. John Marley in 1890, on "The Cleveland and South Durham Salt Industry."¶ These authors reproduce many sections already previously printed by the writer, but add many new ones. As the various *Transactions* are readily accessible, it is not advisable to reproduce them here, except in especial reference to anhydrite.

The earliest borings were at Woodhead, near Great Smeaton, for General Lambton, in 1789, and were carried to a depth of 445 feet in search of coal. They passed through much gypsum, underlain by 190 feet of white sandstone.

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* *Trans. Inst. M.E.*, vol. i., page 342.

† *Reports of the British Association for the Advancement of Science for* 1880, 1881, *and* 1889.

‡ *Proceedings of the Institution of Civil Engineers*, vol. xc., page 131.

§ *Transactions of the Manchester Geological Society*, vol. xix., page 564.

‖ *Quarterly Journal of the Geological Society*, 1888, vol. xliv., page 76.

¶ *Trans. Inst. M.E.*, vol. i., page 339.

In 1809, a boring was put down 666 feet, at a point 2 miles north-west of Woodhead, by Mr. Allan, M.P., proving red sandstone and clays, apparently of Keuper Waterstone age.

In 1856, the Kirklevington boring was put down for coal, for Lord Falkland, and carried to a depth of 710 feet; the locality is east of Woodhead; the beds were alternations of sandstone and clay, the last 90 feet containing much gypsum. Here the beds were obviously Keuper. Magnesian Limestone bands were stated to have heen found, but Mr. P. S. Reid informed the writer that they were not part of the Magnesian Limestone formation. Mr. Reid had charge of the boring, which was carried on till 1858.[*]

In 1867, the Coatham boring[†] was carried out, which proved:—

	Feet.
Lower Lias	165
Rhætic	58
Keuper Marls with gypsum	118
	341

In none of these borings does rock-salt or anhydrite occur; the former was first discovered in this area in 1863 in a boring made for Messrs. Bolckow & Vaughan, at Middlesbrough. The boring was commenced in 1859 in search of water. The following is an abstract, omitting Drift, and of the boring at South Bank, Eston:—

	Middlesbrough.[*]		South Bank, Kston.[†]	
	Ft.	In.	Ft.	In.
Upper Gypseous Marls	86	0	453	0
Red Sandstone and Marls	902	6	836	6
Lower Gypseous Marls	132	8	200	6
Rock-salt	114	10	148	8
Magnesian Limestone	7	4	—	

[*] *Trans. Inst. M.E.*, vol. i., page 352. [†] *Ibid.*, page 356.

Careful study of the sections extending from Hartlepool to South Bank, Eston, shows that the Upper Gypseous Marls are confined to the south side of the Tees, except a strip west of Port Clarence; they are absent to the north and thicken to the south and east. All authorities agree that they are of Keuper Marl age. The Red Sandstones and Marls are no less than 1,117 feet thick at the Imperial Ironworks, Middlesbrough;[‡] they thin northwards to 355 feet at the Cement-works, West Hartlepool;[§] the sandstone predominates in the upper part and marls in the lower part. These beds are believed by Mr. W. J. Bird to be Triassic, and to belong to the Bunter portion.

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[*] *Trans. Inst. M.E.*, vol. i., page 365.

[†] *Ibid.*, vol. i., page 366

[‡] *Ibid.*, vol. i., page 355.

[§] *Ibid.*, page 342.

The Lower Gypseous Marls, extending from Hartlepool to Eston, are generally about 200 feet in thickness ; they thin westwards, and have been variously referred to the Trias and Permian by various authorities.

The Saliferous beds are invariably capped by a bed of anhydrite, usually resting on the bed known as "rotten marl," which has caused the collapse of many boreholes. Immediately beneath is the rock-salt : this attains a maximum thickness of 119 feet, which is largely pure salt, and the remainder consists of alternations of impure salt, gypsum, anhydrite and Marl. Below the salt-beds is the lower anhydrite, averaging 30 to 40 feet, and reaching its maximum of 265 feet at Warren Cement-works, Hartlepool.[*] Mr. W. J. Bird points out that the absence of the salt-beds under the Tees valley may point "to a wash-out," which is much in accordance with the same phenomenon under the Weaver valley south of Northwich. The saliferous beds vary from 39 feet at Port Clarence[†] (Newcastle Chemical Company) and Seaton Carew[‡] 38 feet 7 inches, to 159 feet at Messrs Bell Brothers' trial-hole, Port Clarence.[§]

The Magnesian Limestone has invariably been found whenever the lower anhydrite-bed has been penetrated. Its maximum thickness occurs in the Seaton Carew[‖] experimental borehole, where it is no less than 888 feet thick. The following is an abstract of it, in descending order :—

	Thickness. Feet.	Depth from Surface. Feet.
Alternation of sandstone and marls	289	289
Marls with gypsum and anhydrite	194	483
Anhydrite, with black joints	39	522
Alternations of Magnesian Limestone, blue shale, anhydrite, gypsum, oil and brine	888	1,410
Coal-measures, coal, fire-clay and sandstone...	404	1,814

The boring at Greatham[¶] is the most northern that has proved the salt-bed northward ; at Seaton Carew[**] it has disappeared. The boring was carried out by Messrs. Vivian & Co., some portions being bored at the rate of 112 feet in 24 hours. It was bored at Marsh House[††] for the Greatham Salt-boring Company, Limited :—

No.	Description of Strata.	Thickness.		Depth from Surface.	
		Ft.	In.	Ft.	In.
1	Drift	71	11	71	11
2	Red sandstone	300	7	372	6
3	Red sandstone, with beds of marl ...	77	0	449	6
4	Red sandstone	15	2	464	8
5	Red sandstone, with beds of marl ...	114	7	579	3
6	Red sandy marl	8	6	587	9
7	Red marl, with blue joints	8	6	596	3

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[*] *Trans. Inst. M.E.*, vol. i., page 342.

[†] *Ibid.*, page 357.

[‡] *Ibid.*, page 343.

[§] *Ibid.*, page 350.

[‖] *Ibid.*, page 343.

[¶] *Ibid.*, page 346.

[**] *Ibid.*, page 343.

[††] *Ibid.*, page 346.

No.	Description of Strata.	Thickness. Ft.	Thickness. In.	Depth from Surface. Ft.	Depth from Surface. In.
8	Red sandy marl	21	3	617	6
9	Red marl	20	3	637	9
10	Red marl, with blue joints	21	8	659	5
11	Red marl, with veins of gypsum ...	18	8	678	1
12	Red marl, with veins of gypsum, and blue joints	106	11	785	0
13	Red marl, with veins of gypsum, and blue spots	68	2	853	2
14	Red marl, with veins of gypsum ...	9	10	863	0
15	*Anhydrite*	11	0	874	0
16	Red marl (rotten)	15	0	889	0
17	Rock-salt	57	2	946	2
18	Rock-salt and *anhydrite*, mixed ..	14	3	960	5
19	Rock-salt	11	4	971	9
20	*Anhydrite*	1	0	972	9

Mr. E. Wilson, in the paper already referred to, shows that "there are three distinct views at present prevailing with regard to the geological age of the saliferous deposits of the Durham district." First, that originated by Sir Andrew Ramsay, that the principal bed of rock-salt belongs to the Keuper, and that the lower beds of rock-salt, marls, limestone, gypsum, and anhydrite are Upper Permian. Second, that of Prof. Lebour, that all the saliferous measures belong to the Permian, and are overlain by Bunter Beds. Third, that all the strata above the continuous Magnesian Limestone belong to the Keuper division of the Triassic rocks. The writer is of opinion that the late Sir Andrew Ramsay's views were correct, but he agrees with Mr. E. Wilson that the upper beds are all Keuper, no Bunter being present.

The writer is also of opinion that the anhydrite-beds of North Lancashire are of Permian age, like those of Durham, and are overlain by Keuper beds; also that the St. Bees Sandstone is referable to that division, and not to the Bunter, as now stated by the officers of the Geological Survey. The absence of salt in Furness of Permian age agrees with the Hartlepool section, while the presence of Keuper salt at Walney Island harmonizes with the discoveries at Middlesbrough.

APPENDIX.

No. 2 Boring at Rampside, North Lancashire.

No.	Description of Strata.	Thickness of Strata. Ft.	Thickness of Strata. In.	Depth from Surface. Ft.	Depth from Surface. In.
1	Glacial drift, chiefly clay...	98	0	98	0
2	Red sandstone	1,102	0	1,200	0
3	Red shale ...	8	0	1,208	0
4	Red sandstone ..	27	1	1,235	1
5	Red shale, with gypsum ...	90	0	1,325	1
6	Red shale ...	21	8	1,346	9
7	Red grit ...	4	0	1,350	9
8	Red shale, with gypseous conglomerates...	14	8	1,365	5
9	Red shale and sandstone ...	8	7	1,374	0
10	Red shale ...	4	0	1,378	0
11	Sandstone mixed with gypsum	3	0	1,381	0

No. 2 BORING.—*Continued.*

No.	Description of Strata.	Thickness of Strata. Ft.	In.	Depth from Surface. Ft.	In.
12	Red shale, sandstone and gypsum	21	8	1,402	8
13	Red shale	10	0	1,412	8
14	Red shale and sandstone	8	8	1,421	4
15	Red shale	6	10	1,428	2
16	Red shale and gypsum	23	2	1,451	4
17	Red shale, gypsum and *anhydrite*	12	3	1,463	7
18	Red shale and gypsum	7	7	1,471	2
19	Red shale, gypsum and *anhydrite*	10	8	1,481	10
20	*Anhydrite*	9	10	1,491	8
21	Green shale	0	5	1,492	1
22	Red shale, gypsum and green shale	11	4	1,503	5
23	Red shale and *anhydrite*	6	3	1,509	8
24	Red shale and gypseous conglomerate	11	8	1,521	4
25	*Anhydrite*	11	9	1,533	1
26	*Anhydrite* and gypsum	2	10	1,535	11
27	*Anhydrite*	36	1	1,572	0
28	Gypsum and *anhydrite*	10	10	1,582	10
29	*Anhydrite*	65	2	1,648	0
30	Black sandstone and gypsum	42	9	1,690	9
31	Purple shale	8	5	1,699	2
32	Purple shale and gypsum	9	9	1,708	11
33	Blue shale and gypsum	6	4	1,715	3
34	Fine blue shale, thin grey sandy beds	257	9	1,973	0
35	Hard black and white grits	2	0	1,975	0

ABSTRACT.—

1	Glacial Drift	98	0	98	0
2	Red sandstones	1,137	1	1,235	1
3	Shales, with *anhydrite* and gypsum	480	2	1,715	3
4	Grey limestones (absent)			—	
5	Fine blue shale	257	9	1,973	0
6	Black and white grit	2	0	1,975	0

No. 4 BOREHOLE, GLEASTON.

No.	Description of Strata.	Thickness of Strata. Ft.	In.	Depth from Surface. Ft.	In.
1	Glacial drift	23	0	23	0
2	Red sandstone	14	0	37	0
3	Soft red shale	1	0	38	0
4	Red sandstone	268	0	306	0
5	Stone, sand and shale	1	0	307	0
6	Red shale	28	0	335	0
7	Red sandy shale, gypsum-joints	16	0	351	0
8	Red and green shale with gypsum-joints	7	0	358	0
9	Red sandy shales, with gypsum-joints	22	0	380	0
10	Red sandy shales, with gypsum and "gravel"	14	0	394	0
11	Red sandy shales	155	0	549	0
12	Strong band of grey sandstone	0	3	549	3
13	Red sandy shale, gypsum-joints	11	3	560	6
14	*Anhydrite*	33	6	594	0
15	Rotten red shale	5	0	599	0
16	Light brown magnesian limestone	11	0	610	0
17	Dark brown magnesian limestone	43	0	653	0
18	Magnesian limestone	11	0	664	0
19	Strong blue sandy shale	64	1	728	1

ABSTRACT.—

1	Glacial Drift	23	0	23	0
2	Red sandstone	283	0	306	0
3	Shale and marls, *anhydrite* and gypsum	293	0	599	0
4	Magnesian Limestone	65	0	664	0
5	Blue sandy shale	64	1	728	1

No. 1. BOREHOLE, SOWERBY WOOD.

No.	Description of Strata.	Thickness of Strata. Ft.	In.	Depth from Surface. Ft.	In.
1	Glacial drift, clay and sand ...	110	0	110	0
2	Dark grey sand ...	1	0	111	0
3	Soft dark red sandstone	6	0	117	0
4	Dark red and grey sandstone ...	5	9	122	9
5	Dark red and grey sandstone, very soft	0	6	123	3
6	Red sandstone ...	3	8	126	11
7	Soft red sandstone	9	7	136	6
8	Red marl	2	0	138	6
9	Broken red sandstone	116	6	255	0
10	Red sandstone ...	80	6	335	6
11	Red sandstone and joints of marl ...	10	6	346	0
12	Red sandstone ...	68	0	414	0
13	Strong red sandstone ..	16	0	430	0
14	Jointed red sandstone ...	6	9	436	9
15	Strong red marl, with baryta-joints	53	8	490	5
16	Strong red and grey sandy marls, with baryta-joints ...	60	7	551	0
17	Red clay, with soft clay joints ...	10	6	561	6
18	Strong red marl, with gypsum ...	4	0	565	6
19	Strong red shales, sandstone, gypsum	63	0	628	6
20	Red and yellow sandstone ..	7	6	636	0
21	Red sandstone ...	10	0	646	0
22	Red and grey sandstone	10	0	656	0
23	Grey sandstone ...	10	0	666	0
24	Blue and grey sandy shaly sandstone ...	5	0	671	0
25	Close-grained yellow limestone ...	5	0	676	0
26	Close-grained yellow limestone, sparry joints ...	20	0	696	0
27	Jointed red and grey limestone...	2	10	698	10
28	Broken grey limestone	11	6	710	4
29	Grey limestone ...	15	6	725	10
30	Limestone ...	1	0	726	10
31	Strong red and blue shale ...	5	0	731	10
32	Much jointed, hard close-grained grey sandstone...	2	10	734	8
33	Brown sandstone	8	6	743	2
34	Reddish blue shale	2	6	745	8
35	Close reddish sandstone	8	5	754	1
36	Hard white gritstone	0	8	754	9
37	Hard white sandstone	12	4	767	1
38	Hard grey sandstone	0	6	767	7
39	Reddish grey sandstone, very broken	8	9	776	4
40	Grey sandstone, very broken ...	2	8	779	0
41	Reddish grey sandstone	1	0	780	0
42	Red and grey shaly sandstone ...	2	0	782	0
43	Red and blue shale	6	3	788	3
44	Mottled shale ...	8	9	797	0
45	Brown sandstone	4	0	801	0
46	Mottled shale ...	11	11	812	11
47	Very broken red whirlstone, brown spar joints	13	4	826	3
48	Mottled shale ...	7	0	833	3
49	Red whirlstone ...	1	9	835	0
50	Red and grey limestone and shale	7	0	842	0
51	Grey limestone ...	3	2	845	2
52	Grey limestone, with spar joints	28	4	873	6
53	Hard grey gritty sandstone ...	1	0	874	6
54	Hard reddish grey gritty sandstone	10	0	884	6
55	Reddish grey sandstone	2	0	886	6
56	Mottled shale ...	9	6	896	0

ABSTRACT.—

	Ft.	In.	Ft.	In.
Glacial Drift	110	0	110	0
Red Sandstone (St. Bees Sandstone)	326	9	436	9
Shales and marls ..	191	9	628	6
Red, yellow and grey sandstones ..	42	6	671	0
Magnesian Limestones—Grey, red and yellow limestones ...	55	10	726	10
Carboniferous Measures—Shales, mottled sandstone, and whirlstones at base ...	108	2	835	0
Red and grey limestone	38	6	873	6
Reddish grey sandstone	13	0	886	6
Mottled shales ...	9	6	896	0

DISCUSSION ON MR. W. E. GARFORTH'S "SUGGESTED RULES FOR THE RECOVERY OF COAL-MINES AFTER EXPLOSIONS."*

Mr. **William Maurice** (Tibshelf) wrote that he would like to express his appreciation of the valuable suggestions and advice contained in Mr. Garforth's "Suggested Rules for the Recovery of Coal-mines after Explosions." He had not noticed any comments on clause 19A† providing for storage of compressed oxygen. This gas had now become almost a stock remedy in the hands of medical men; it having proved of great value in the treatment of acute pneumonia. Clergymen and others also frequently kept cylinders of oxygen, as a necessary part of a limelight apparatus. It might thus result, if inquiry were made in each mining locality, that there was a supply of this most valuable restorative near at hand, in quantities sufficient to meet any emergency.

DISCUSSION UPON MESSRS. E. B. MARTEN AND EDMUND HOWL'S PAPER ON "THE SOUTH STAFFORDSHIRE MINES-DRAINAGE SCHEME, WITH SPECIAL REGARD TO ELECTRIC-POWER PUMPING."‡

Mr. T. **Vaughan Hughes** (Birmingham) would like to have a definite statement from the authors of the paper as to whether they were going to use a triphase or direct current of some form or other. It seemed a great disadvantage to the South Staffordshire district if the former was not decided upon before the works were actually put down, for the simple reason that the former current would make it invaluable for numerous metallurgical operations as well as for power-supply.

Mr. E. B. **Marten** wrote that no reply could at present be given to Mr. T. Vaughan Hughes' question as to the form of electric current to be used, as it would be supplied by the Electric Corporation, and the pump-motors would have to be adapted to their current. It was well that so important a question should be raised, and he thought due consideration would be given to it when the electric-works were designed.

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* *Trans. Inst. M.E.*, vol. xiv., page 495; vol. xv., pages 134, 210, 249, 261 and 268; and vol. xvi., pages 99, 116 and 226.

† *Ibid.*, vol. xiv., page 503.

‡ *Ibid.*, vol. xvi., page 268.

DISCUSSION ON MR. WM. M. BREWER'S PAPER ON "PROSPECTING IN BRITISH COLUMBIA."*

Mr. T. VAUGHAN HUGHES (Birmingham) remarked that Mr. Brewer had laid stress upon the hiring of Indians. He, however, would advise the members to give the Indians as wide a berth as they possibly could.

The difficulty with which one had to contend in British Columbia was the number of small claims. Mining engineers prospected districts with the view of working minerals, and found claims already pegged out, and they had all kinds of complicated interests to deal with. British Columbia comprized large mineral districts, and the scope for mining engineers was very great; but meanwhile Americans were acquiring every valuable claim, and he hoped that British mining engineers would turn their attention to that part of the world, and do more there in the future than they had done in the past.

DISCUSSION OF MR. W. CARRICK ANDERSON'S PAPER ON "A CONTRIBUTION TO THE CHEMISTRY OF COAL, WITH SPECIAL REFERENCE TO THE COALS OF THE CLYDE BASIN."†

Mr. T. VAUGHAN HUGHES (Birmingham) asked whether Mr. Anderson had made any allowance for the gases that are occluded in the various kinds of coal, and whether he had in any shape or form connected the composition of these gases with the results so far obtained and recorded in his paper. He (Mr. Hughes) looked upon the investigation as a most important one, and he expected that very great results would follow from it, as it was a matter of great interest to know how this mineral which we used so largely in this country was made up.

Mr. W. CARRICK ANDERSON wrote that the question asked by Mr. Hughes, as to whether he had made any allowance for the gases that were evolved by different kinds of coal, referred possibly to that part of his investigations which dealt with the loss that coals underwent on being heated to 300° Cent. in the absence of air. This loss was considerable, ranging from 6·4 to 21·8 per cent. in the samples upon which he experimented. The figures given would, of course, include any gaseous matter occluded in the coals and capable of being evolved at a more elevated temperature: but the amount of this was negligible, as compared with the weights stated above. So far as the experiments of investigators on this particular point went, the amount of occluded gas in bituminous coals rarely, if ever, reached 0·20 per cent. of their weight. He had not yet been able to make full analyses of the gases evolved under the conditions stated in his paper, or to draw any conclusions from this part of the investigation as to the nature of the decomposition that took place here, or under the ordinary conditions obtaining in a coal-seam.

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* *Trans. Inst. M.E.*, vol. xvi., page 291. † *Ibid.*, vol. xvi., page 335.

The following paper by Messrs. Heise and Thiem on "Experiments on the Ignition of Fire-damp and Coal-dust by means of Electricity," was taken as read:—

EXPERIMENTS ON THE IGNITION OF FIRE-DAMP AND COAL-DUST BY MEANS OF ELECTRICITY.*

By BERGASSESSOR HEISE and DR. THIEM.

These experiments were conducted in the experimental drift at Gelsenkirchen, in order to determine to what extent electrically-driven machinery is dangerous in fiery or dusty mines. The chief danger that arises from the use of electricity lies in such appliances as either emit sparks or necessitate portions being raised to a white heat, either continuously or intermittently, when the apparatus is in regular work. In addition to these risks, danger may also arise from accidental occurrences, such as injury to conductors, short-circuiting, etc.: such accidents are difficult to investigate experimentally, because the circumstances attending each particular case cannot well be imitated. Moreover, the importance of such occurrences must not be exaggerated: with even fairly good installations (which must always be postulated in mining work) they are extremely rare, and can with attention be almost absolutely prevented at really dangerous points.

The object of the trials was accordingly to test the safety of such electric appliances as are in current use, and which may be looked upon as more or less liable to constant danger, when they are exposed to explosive mixtures of pit-gas or coal-dust.

Description of the Experimental Station.—The experimental station erected in 1894 consists of an elliptical gallery 111·55 feet (34 metres) long, 6·07 feet (1·85 metres) high, and 4·23 feet (1·35 metres) wide, built of elliptical iron hoops and stout planking. It is furnished with windows and safety-holes closed by means of paper. One end is closed by means of a brick wall, and at this end a length of 16·73 feet (5·1 metres) can be shut off by means of a paper diaphragm, so as to enclose an explosion-chamber of 353 cubic feet (10 cubic metres).†

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* "Versuche betreffend die Entzündlichkeit von Schlagwetter-Gemischen und Kohlenstoff-Aufwirbelungen durch die Wirkungen der Elektrizität, ausgeführt auf der Versuchsstrecke der Westfälischen Berggewerkschaftskasse, auf Zeche Consolidation iii./iv. bei Gelsenkirchen," *Glückauf*, 1898, vol. xxxiv., pages 1 to 7, 25 to 33, and 45 to 52. Translated, and in part abridged, by Prof. H. Louis.

† *Trans. Inst. M.E.*, vol. ix., page 250.

The pit-gas used in these experiments was derived from some abandoned workings which have been walled off. The gas is under a pressure of 1·38 inches (35 millimetres) of water, but its rate of discharge can be accelerated by the use of a small steam-jet inserted in the delivery-pipe. The gas is passed through an ordinary gas-meter and thus measured. Inside the explosion-chamber, there is a fan so arranged as to intimately mix the gases in it. The pit-gas contains about 38·4 per cent. of methane, and in the experiments an explosive mixture containing 9 per cent. of methane was used. The coal-dust used was artificially prepared by very fine grinding of a highly combustible coal.

The electric current employed was furnished by the Bochum-Gelsenkirchen Electric Tramway Company, and amounted to 10 ampères at 500 volts. This electric current could be used to work a motor of 10 horsepower, by means of which either a continuous-current dynamo of 4·5 horsepower at 110 volts, or an alternating-current dynamo of 4 horsepower at 110 volts could be actuated. It was thus possible to employ either the direct current at 500 volts, the continuous-current up to a maximum of 170 volts and 50 to 60 ampères, or an alternating-current up to 120 volts and 60 to 70 ampères; and by a transformer the latter could also be used at a tension of 2,000 volts. Finally, an accumulator-current, such as is used for pit-lamps, up to 8 volts was also available. The necessary switch-board, resistances, ammeter, voltmeter, etc., were also provided, and all the instruments were standardized by Messrs. Siemens and Halske before they were despatched to the mine.

Experiments with Incandescent Lamps.—As various kinds of lamps gave different results, it is necessary to explain in the first place wherein the differences in their construction consist. The illuminating-power of an incandescent lamp depends on the quantity of electric energy supplied to it, about 3 to 3½ watts being usually allowed for each standard candle, a 16 candle-power lamp thus consuming about 50 watts. Incandescent lamps are arranged to work at 2 to 250 volts. The strength of the current may be calculated from the tension used and the illuminating-power required. The sectional area of the carbon filament depends upon the quantity of current, and its length upon the tension of the latter; hence it follows that low-voltage lamps with strong currents require short and thick filaments, high-voltage lamps with comparatively weak currents long and slight filaments. It is self-evident that filaments of the former type are less easily broken than those of the latter.

A few preliminary experiments were made, in order to determine to what extent glowing filaments might constitute a source of danger in an explosive atmosphere.

The results are shown in Table I.

TABLE I.—EXPERIMENTS WITH BARE GLOWING FILAMENTS IN AN EXPLOSIVE MIXTURE OF FIRE-DAMP.

No. of Experiment.	The Filament was taken from a Lamp working at		Voltage actually used to bring the Filament to a Glow.	Nature of Current.	Results and Observations.
	Candle-power.	Volts.	Volts.		
1	100	100.	85	Dynamo—Continuous	Gas ignited as soon as portions of the filaments were raised to whiteness. The filament broke, apparently owing to the force of the explosion.
2	35	100	100	"	Ignition when the filament was raised to whiteness; it was uninjured, and continued to glow.
3	16	100	100	"	" "
4	16	100	100	"	Ignition upon the filament burning through.
5	2	6	6	Accumulator—Continuous	" "
6	2	6	4	"	Ignition after about ¼ minute. when the filament became white-hot and burnt through without sparking.

These experiments show that a white-hot filament is capable of igniting fire-damp and that ignition takes place at the latest when the filament burns through, even in cases where the strength and tension of the current (*e.g.*, experiment No. 6, with only 4 volts) are so low that there seems to be no possibility of producing sparks. It may further be deduced that every incandescent lamp may become a source of danger whenever it is possible for the filament to remain uninjured after the glass bulb is broken.

In spite of the above unfavourable results with bare filaments, the actual experiments performed by breaking incandescent lamps in explosive mixtures of gas gave unexpectedly satisfactory results with certain classes of lamps. In these experiments, the lamps were attached by their collars to an iron rod by which they were suspended in the gallery; and by means of a cord the rod could be swung, so as to cause the lamp to strike against the walls of the gallery and thus be broken.

These experiments showed a surprising uniformity in their results, in spite of the large number tried: a proof that the manufacture of incandescent lamps has reached a high pitch of perfection, and is capable of producing practically uniform lamps. It also shows that the conditions of the experiments in general could be kept as uniform as need be desired. The results are given in Table II.

It here appears that small 2 candle-power lamps worked at 6 volts are unsafe (experiment No. 5); the reason why ignition was not more regularly obtained with these lamps is probably because the lamps were not secured in any proper fastening; in order to avoid introducing the accumulators into the explosion-chamber the lamps were secured by their platinum loops to a couple of wires, but it was found difficult to obtain a contact that would not fail when the lamp received a blow. Probably these contacts had already been broken before the lamp was shattered, in those experiments that gave no ignition. The number of these experiments was therefore very limited, because experiment No. 5 had already demonstrated the danger, greatly increased by the strength of the short and thick filament, which does not break regularly when the glass does.

The 10 candle-power lamps, working at 65 volts, were proved to be very safe, as they were still safe with an excess of tension equal to 30 per cent. (experiments Nos. 6-21).

The 16 candle-power lamps, with 65 volts normal tension, were unsafe (experiments Nos. 22-30), while lamps of the same illuminating-power at 100 and 150 volts were safe, even with the considerable excesses of tension of 20 and 16 per cent. respectively (experiments Nos. 34-133 and 134-149); in 23 of these experiments (Nos. 111-133) an alternating current was employed, but the nature of the current seems to have no effect upon the result, a conclusion confirmed by experiments on 25 candle-power lamps (Nos. 151-153). Experiment No. 67 was made under abnormal conditions, and will be again referred to.

The 25 candle-power lamps with 110 volts are unsafe even at their normal tensions (experiments Nos. 150-153), whilst they were safe up to an excess of tension of 16·7 per cent. with 150 volts (experiments Nos. 154-172). The 25 candle-power lamps at 220 volts seem also to be safe as far as the filament is concerned, but they are very liable to short-circuiting. In 7 experiments (Nos. 173-179) the lamps were twice (Nos. 178 and 179) short-circuited, causing ignition. It should be explained that these lamps have two long and narrow filaments, and the four wires to which they are attached project considerably beyond the mounting. A blow upon the

TABLE II.—EXPERIMENTS WITH INCANDESCENT LAMPS IN AN EXPLOSIVE MIXTURE OF FIRE-DAMP.

No.	Number of Experiments.	Kind of Current Employed.	Normal Tension. Volts.	Tension Employed. Volts.	Percentage of Excess Tension.	Mode of Conducting the Experiment.	Result.	Other Observations.
						A.—EXPERIMENTS WITH 2 CANDLE-POWER LAMPS.		
1-3	3	Accumulator —Continuous	6	6	—	Lamp broken by striking against an iron plate.	No ignition	Lamp immediately ceased to glow.
4	1	„	6	6	—	Lamp broken by striking against the iron frame of the gallery.	„	„ „
5	1	„	6	6	—	„ „	Ignition	Ignition occurred immediately.
						B.—EXPERIMENTS WITH 10 CANDLE-POWER LAMPS.		
6-15	10	Dynamo—Continuous	65	65	—	Lamp broken by striking against the iron frame of the gallery.	No ignition	In a few cases, slight sparks were observed when the lamp was extinguished.
16	1	„	65	70	7·7	Only the tip of the bulb was broken, keeping the glowing filament intact.	„	The filament became dark, commenced to glow again, and then burnt through.
17-18	2	„	65	70	7·7	Lamp broken by striking against the iron frame of the gallery.	„	Sparks were observed in several cases.
19	1	„	65	75	15·4	„ „	„	
20	1	„	65	80	23·1	„ „	„	
21	1	„	65	85	30·8	„ „	„	

TABLE II.—*Continued.*

No.	Number of Experiments.	Kind of Current Employed.	Normal Tension.	Tension Employed.	Percentage of Excess Tension.	Mode of Conducting the Experiment.	Result.	Other Observations.
C.—EXPERIMENTS WITH 16 CANDLE-POWER LAMPS.								
22-30	9	Dynamo—Continuous	Volts. 65	Volts. 65	—	Lamp broken by striking against the iron frame of the gallery.	No ignition	More frequent appearance of sparks when lamp was extinguished.
31	1	”	65	65	—	” ”	Ignition	—
32	1	”	65	70	7·7	” ”	”	—
33	1	”	65	75	15·4	” ”	”	—
34-44	11	”	100	100	—	Lamp broken by striking against the wooden wall of the gallery.	No ignition	—
45-53	9	”	100	100	—	Lamp broken by striking against the iron frame of the gallery.	”	Slight sparks occasionally seen when lamp was extinguished.
54-56	3	”	100	100	—	Only the tip of the bulb was broken, leaving the glowing filament intact.	”	The filament became dark, glowed again, and burnt through with sparking at the end of 1½ to 2 minutes.
57	1	”	100	110	10	” ”	”	” ”
58	1	”	100	115	15	” ”	”	” ”
59	1	”	100	120	20	” ”	”	” ”
60-66	7	”	100	100	—	The tip of the bulb was broken with the lamp out of circuit, and contact was then made.	”	The filament glowed irregularly in different parts, and burnt through with sparks.
67	1	”	100	100	—	The tip of the bulb of a burning lamp was first broken off, and the lamp then shattered by a second blow.	Ignition	—
68-77	10	”	100	110	10	Lamp broken by striking against the iron frame of the gallery.	No ignition	Sparks often seen when the lamp was extinguished.
78-84	7	”	100	115	15	” ”	”	” ”
85-95	11	”	100	120	20	” ”	”	Sparks regularly observed when the lamp was extinguished.
96-101	6	”	100	125	25	” ”	”	” ”

TABLE II.—C.—EXPERIMENTS WITH 16 CANDLE-POWER LAMPS.—*Continued.*

No.	Number of Experiments.	Kind of Current Employed.	Normal Tension.	Tension Employed.	Percentage of Excess Tension.	Mode of Conducting the Experiment.	Result.	Other Observations.
102-103	2	Dynamo—Continuous	Volts. 100	Volts. 125	25	Lamp broken by striking against the iron frame of the gallery.	Ignition	—
104	1	,,	100	130	30	,, ,,	No ignition	Sparks observed.
105-110	6	,,	100	130	30	,, ,,	Ignition	—
111	1	Alternating	100	110	10	,, ,,	No ignition	—
112-128	17	,,	100	120	20	,, ,,	,,	Sparks regularly observed when the lamp was extinguished.
129-131	3	,,	100	125	25	,, ,,	,,	,, ,,
132	1	,,	100	125	25	,, ,,	Ignition	—
133	1	,,	100	130	30	,, ,,	,,	—
134-135	2	Dynamo—Continuous	150	150	—	,, ,,	No ignition	—
136-143	8	,,	150	165	10	,, ,,	,,	Sparks were observed regularly.
144-146	3	,,	150	170	13·3	,, ,,	,,	Strong sparking was observed.
147-148	2	,,	150	175	16·7	,, ,,	,,	,, ,,
149	1	,,	150	180	20	,, ,,	Ignition	—

D.—EXPERIMENTS WITH 25 CANDLE-POWER LAMPS.

No.	Number of Experiments.	Kind of Current Employed.	Normal Tension.	Tension Employed.	Percentage of Excess Tension.	Mode of Conducting the Experiment.	Result.	Other Observations.
150	1	Dynamo—Continuous	110	110	—	Lamp broken by striking against the iron frame of the gallery.	Ignition	—
151-152	2	Alternating	110	110	—	,, ,,	No ignition	—
153	1	,,	110	118	7·3	,, ,,	Ignition	—

TABLE II.—D.—EXPERIMENTS WITH 25 CANDLE-POWER LAMPS.—*Continued.*

No.	Number of Experiments.	Kind of Current Employed.	Normal Tension.	Tension Employed.	Percentage of Excess Tension.	Mode of Conducting the Experiment.	Result.	Other Observations.
			Volts.	Volts.				
154-155	2	Dynamo—Continuous	150	150	—	Lamp broken by striking against the iron frame of the gallery.	No ignition	Strong sparking was observed.
156-162	7	„	150	160	6·7	„ „	„	
163-168	6	„	150	165	10	„ „	„	
169-171	3	„	150	175	16·7	„ „	„	
172	1	„	150	180	20	„ „	Ignition	
173-175	3	„	220	230	4·5	„ „	No ignition	Very strong sparking was observed.
176-177	2	„	220	245	11·3	„ „	„	
178	1	„	220	240	9	„ „	Ignition	Two of the four platinum wires projecting from the mounting came into contact and fused together, causing short-circuiting.
·179	1	„	220	260	18	„ „	„	Short-circuiting caused by fragments of filament, two platinum-wires fused.
E.—EXPERIMENTS WITH 35 CANDLE-POWER LAMPS.								
180-190	11	Dynamo—Continuous	100	100	—	Lamp broken by striking against the iron frame of the gallery.	No ignition	—
191-192	2	„	100	100	—	„ „	Ignition	—
193	1	„	100	100	—	Only the tip of the bulb was broken off, leaving the glowing filament intact.	No ignition	The filament became darker, glowed again, and burnt through.
194	1	„	100	130	30	Lamp broken by striking against the iron frame of the gallery.	Ignition	—
F.—EXPERIMENTS WITH ONE 50 CANDLE-POWER AND ONE 100 CANDLE-POWER LAMPS.								
195	1	Dynamo—Continuous	100	100	—	Lamp broken by striking against the iron frame of the gallery.	Ignition	—
196	1	„	100	100	—	„ „	„	—

lamp would therefore readily bring these wires into contact and produce short-circuiting. It may be assumed that such a lamp could be rendered safe by a proper construction preventing any short-circuiting.

The 35, 50 and 100 candle-power lamps for 100 volts are unsafe (experiments Nos. 180-196).

All kinds of lamps that were tested and found safe at normal tensions undoubtedly become unsafe when the current-tension greatly exceeded the normal, and thus each lamp has its limit of safety. This does not cause any particular danger, because, although it does happen in practice that the normal tension is exceeded, but such excess can be easily kept within definite limits.

When the lamps were broken in the explosion-chamber, sparking was frequently observed; it increases with higher tension, but seems to be without effect upon the safety of the lamp.

The individual results may be summarized as follows, it being noted that in (*a*) the danger is increased owing to the probability of the filament remaining intact when the lamp is broken, and that in (*h*) there is great danger of short-circuiting:—

(*a*)	2	candle-power lamps for	6	volts and	0·80	ampère—	unsafe.
(*b*)	10	,,	65	,,	0·46	..	safe.
(*c*)	16	,,	65	,,	0·77	,,	unsafe.
(*d*)	,,	,,	100	,,	0·50	,,	safe.
(*e*)	,,	,,	150	,,	0·33	,,	safe.
(*f*)	25	,,	110	,,	0·73	,,	unsafe.
(*g*)	,,	,,	150	,,	0·58	,,	safe.
(*h*)	,,	,,	220	,,	0·38	,,	safe.
(*j*)	35	,,	100	,,	1·00	..	unsafe.
(*k*)	50	,,	100	,,	1·50	,,	unsafe.
(*l*)	100	,,	100	,,	3·00	,,	unsafe.

The first point here brought out is that the measure of electrical energy expressed in the luminous power of the lamps has no definite influence upon their danger. Lamps of high illuminating-power are under certain conditions notably safer than lamps of low power. The danger of the lamps does, however, increase with the strength of the current, or, what is the same thing, with the increasing thickness of the filaments; current-strengths up to 0·6 ampère are safe.

In order to understand the reason for this, the occurrences that take place when a lamp-bulb is broken must be examined. The external (comparatively cold) air rushes into the strongly heated, practically, vacuous bulb, and is still further cooled by expansion; the temperature of the glowing filament is thereby so far reduced that in many lamps it becomes quite dark for a few seconds. If the filament has remained uninjured it at once glows again, and burns through in a very short time. These phenomena may be readily observed in any incandescent lamp when the tip of the bulb is carefully broken off with a pair of pliers. The filament gets darkest in those lamps that have a very thin filament, or low current-strength ; the tension is of less moment in this respect. If at the instant that the lamp is shattered and the filament cooled down, the latter is also broken, its temperature in certain classes of lamps is insufficient to ignite an explosive mixture.

The cooling-down of the filament is therefore the first requisite for the safety of an incandescent lamp. Whether the degree of cooling is sufficient in an untested form of lamp may be determined, with a little experience, by direct experiment. A lamp can only be considered safe when the air on rushing in brings the filament down to a dull red heat.

The destruction of the filament when the bulb is broken, the second condition for the safety of a lamp, does not occur uniformly with all lamps. In low-voltage lamps which have short, thick, and therefore substantial filaments, it is often possible to shatter the bulb by a careful blow without injuring the filament. On these grounds alone, such lamps, which are employed for mining purposes in the form of accumulator-lamps, must be considered unsafe.

On the other hand, the filament broke with the greatest regularity in all lamps with a tension of at least 65 volts, these having a relatively long filament and a large bulb. It happened often that a light blow would break the filament without damaging the glass bulb, while in special experiments outside the explosion-chamber it was never found possible to break the bulb, and at the same time keep the brittle filament intact. Even when bulbs were crushed most carefully in a vice, it was only found possible to keep the filament uninjured in one-half of the trials ; such careful breaking need not, however, be taken into consideration in mining practice, more especially when the bulb is protected by a glass cover.

Although it thus seems impossible for a bulb to be shattered by any of the accidents of mining without the filament being at the same time destroyed, a special case may yet arise in which an explosive mixture of gas would come into contact with the glowing filament. The most vulnerable part of the bulb is its tip, and this can be easily broken off by a blow that would leave the rest of the bulb uninjured. A number of experiments were directed towards ascertaining whether accidents of this kind might be attended with danger ; two series of experiments were performed. In the first, a glowing lamp, in circuit, was suspended in the explosive mixture, and the tip of the bulb was broken off by a suitably

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s brought into suspension, but when explosive gas-mixtures were g tested, the current was only made to pass after the mixture had een made. The results given in Table III. show no difference between continuous and alternating currents. The lamps caused no ignitions with dust either by itself or in non-explosive mixtures of pit-gas (4 to 5 per cent. of methane): neither was any increase in the size of the arc or any spreading of flame noticeable, even when in one case the strength of the current was raised to 30 ampères (experiment No. 5). When the coal-dust was thrown up, the explosion-chamber became if anything darker, a circumstance that could only be due to the particles of dust suspended in the air. Explosive mixtures of gas, on the other hand, were invariably ignited on the instant that the lamp was thrown into action.

TABLE III.—EXPERIMENTS WITH ARC-LAMPS IN COAL-DUST AND MIXTURES OF GAS.

No. of Experiment.	Nature of Current.	Strength of Current.	Tension of Current.	Method of Conducting the Experiment.	Duration of Experiment.	Results and Observations.
		Ampères.	Volts.		Minutes.	
1	Continuous	6	38	Lamp burning, dust flung up	2	No ignition; flame not increased.
2	„	6	38	Made 4 per cent. mixture of pit-gas; put lamp in circuit, flung up coal-dust	2	„
3	„	6	38	Made 6 per cent. mixture of pit-gas; put lamp into action	—	Immediate ignition.
4	„	6	38	Made 7 per cent. mixture of pit-gas; put lamp into action	—	„
5	Alternating	30	Not measured	Lamp burning, dust thrown up	2	No ignition; flame not increased.
6	„	20	„	Made 5 per cent. mixture of pit-gas; put lamp into action; flung up coal-dust	4	„
7	„	6	40	Made explosive mixture of pit-gas; put lamp into action	—	Immediate ignition.

Experiments on Sparks produced when Contact is broken at a Switch.—The switches used in practice are so arranged as to interrupt the current without the production of strong sparks. This is necessary, because the arc formed when a current is interrupted might otherwise heat, damage or fuse the working-surfaces of the switch. The problem is an easy one with low-current strengths and tensions, and especially for circuits free from self-induction, because the spark produced in such cases is always small. With great strength, high tension and much self-induction, on the other hand, the certain prevention of any arc renders special constructions necessary, one of two methods being adopted. In the one, the current is simultaneously interrupted in several places; and in the other, the contacts are separated as far from each other and as rapidly as possible.

The subdivision of sparking produced by the first method is best attained by multipolar switches, which interrupt the positive and negative conductors simultaneously, the contact-surfaces being at the same time made as large as conveniently possible, so as to reduce the current-density per unit of area.

The second method depends on the fact that an arc at a given tension can extend only to a certain length, and is extinguished when the terminals are farther apart. It also needs a certain time for its production, so that it is destroyed by very rapid interruption of the circuit, and for this purpose switches are provided with springs, which snap rapidly and jerk the terminals far apart from each other.

Experiments were performed on four different switches, namely :—

A switch for incandescent lamps for 4 ampères, with very rapid action.

A bipolar switch for 25 ampères, with very rapid spring-action.

A lever switch sliding over contacts, for about 15 ampères, capable of being worked rapidly or slowly.

A mercury switch for 50 ampères.

Besides these, a short circuit from an accumulator was also broken by separating the two conducting wires by hand.

These experiments are recorded in Table IV.

The incandescent-lamp switch admitted of contact being broken without danger in a 100 volts current of a strength of 0·5 to 1·0 ampère (experiments Nos. 1 and 2); but when the strength rose to 2 ampères (experiment No. 3) ignition took place. This particular current was an ordinary lamp current without much self-induction.

The bipolar switch for 25 ampères produced ignitions with a current of over 4 ampères, in which resistances were inserted in place of lamps (experiments Nos. 4-6). When self-induction was increased by the introduction of a few spirals into the circuit, a lower current strength sufficed to cause ignition (experiments Nos. 7-9).

The most extensive series of experiments was tried with the lever switch for 15 ampères When contact was broken rapidly in a con-

TABLE IV.—EXPERIMENTS ON SPARKS PRODUCED IN SWITCHES.

No. of Experiment.	No. of Times Contact Broken.	Current Tension.	Current Strength.	Nature of Current.	Details of Current.	Results.	Observations.
A.—SWITCH FOR INCANDESCENT LAMPS FOR 4 AMPÈRES, WITH RAPID ACTION (COVER REMOVED).							
		Volts.	Ampères.				
1	40	100	0·5	Dynamo—Continuous	One 16 candle-power lamp in circuit.	No ignition	—
2	40	100	1·0	”	One 35 ” ”	”	—
3	5	100	2·0	”	Two 35 ” ”	Ignition.	At the 5th trial.
B.—BIPOLAR SWITCH FOR 25 AMPÈRES, WITH SPECIALLY RAPID SNAP-ACTION.							
4	40	100	2–4	Dynamo—Continuous	Resistances interposed in circuit.	No ignition	Small sparks visible with 3 ampères.
5	4	100	5–7	”	” ”	Ignition	At the 4th trial.
6	31	100	4 7·5	”	” ”	”	At the 31st trial.
7	45	100	0·75-1·5	”	Resistances interposed with a few spirals to increase self-induction, which was still slight.	No ignition	Sparks visible even with 1 ampère.
8	45	100	2–2·5	”	” ”	”	—
9	2	100	3–4·5	”	” ”	Ignition	At the 2nd trial.

TABLE IV.—*Continued.*

No. of Experiment.	No. of Times Contact Broken.	Current Tension.	Current Strength.	Nature of Current.	Details of Current.	Results.	Observations.
C.—LEVER SWITCH WITH SLIDING CONTACTS, CAPABLE OF WORKING FAST OR SLOWLY.							
		Volts.	Ampères.				
10	40	100	0·5	Dynamo—Continuous	One 16 candle-power lamp at 100 volts in circuit.	No ignition	Contact broken rapidly.
11	40	100	0·75	„	One 25 „ 100 „		
12	40	100	1·0	„	One 32 „ 100 „	„	„ „
13	40	100	1·5	„	Two 25 „ 100 „	„	„ „
14	5	100	1·75	„	One 25 candle-power lamp at 100 volts in circuit, and one 32 candle-power at 100 volts.	Ignition	At the 5th trial. Contact broken rapidly.
15	1	120	1·2	„	One 32 candle-power lamp at 100 volts in circuit.	„	At the 1st trial. Contact broken slowly.
16	30	100	0·5	„	One 16 „ 100 „	No ignition	Contact broken slowly.
17	30	100	1·0	„	One 32 „ 100 „	„	„ „
18	42	100	1·0	„	One 32 „ 100 „	„	Contact broken so slowly that small arcs formed and continued for a short time.
19	5	100	1·5	„	Two 25 „ 100 „	Ignition	At the 5th trial. A small arc had formed, and continued for about ¼ minute when it fired the gas.
20	30	150	0·37	„	One 16 „ 150 „	No ignition	Contact broken very rapidly.
21	30	150	0·37	„	One 16 „ 150 „	„	„ slowly.
22	45	150	0·58	„	One 25 „ 150 „	„	„ at times rapidly, at times slowly.
23	1	150	0·58	„	One 25 candle-power lamp at 150 volts in circuit, and the secondary coils of a small alternating current-transformer with very high self-induction.	Ignition	—
24	2	100	0·23	„	Circuit included the field-magnet coils of a 6½ horsepower continuous-current motor (*LH5*) for 100 volts, so as to produce great self-induction.	No ignition	Contact broken slowly.
25	1	100	0·23	„	„ „	Ignition	„ rapidly. An arc about 0·2 inch long formed, due to self-induction.

TABLE IV. C.—LEVER SWITCH WITH SLIDING CONTACTS, CAPABLE OF WORKING FAST OR SLOWLY.—*Continued.*

No. of Experiment.	No. of Times Contact Broken.	Current Tension.	Current Strength.	Nature of Current.	Details of Current.	Results.	Observations.
		Volts.	Ampères.				
26	1	100	0·11	Dynamo—Continuous	Circuit included the field-magnet coils of a 6¼ horsepower continuous-current motor (*LH 5*) for 100 volts; together with the field-magnet coils of a smaller continuous-current motor; very great self-induction.	Ignition	Contact broken rapidly, an arc being thus produced.
27	50	120	0·55	Alternating	One 16 candle-power incandescent lamp at 100 volts in circuit.	No ignition	Contact broken slowly.
28	50	120	0·73	„	One 25 candle-power incandescent lamp at 110 volts in circuit.	„	„ „
29	50	120	1·2	„	One 35 candle-power incandescent lamp at 100 volts in circuit.	„	„ „
30	20	120	0·55	„	One 16 candle-power incandescent lamp at 100 volts in circuit.	„	„ rapidly.
31	15	120	0·73	„	One 25 candle-power incandescent lamp at 110 volts in circuit.	Ignition	At the 15th trial. Current broken rapidly.
D.—MERCURY SWITCH FOR 50 AMPÈRES.							
32	11	100	1·0	Accumulator	One 35 candle-power incandescent lamp at 100 volts in circuit.	Ignition	At the 11th trial.
E.—BREAKING THE SHORT CIRCUIT OF AN ACCUMULATOR IN TEST-TUBE.							
33	40	4	20	Accumulator	Copper electrodes.	No ignition	Sparks produced.
34	40	8	25	„	„ „	„	Strong sparks produced.
35	40	8	25	„	Iron electrodes.	„	„ „

tinuous current of 100 to 150 volts tension, ignition first occurred with a strength of 1·75 ampères. If, however, contact was broken slowly and the spark thus purposely prolonged as an arc, ignitions were produced at 1·2 and 1·5 ampères (experiments Nos. 10-14 and 15-22). Results were still more unsatisfactory when an exceptionally high self-induction was produced in the circuit (experiments Nos. 23-26); in such cases, a strength of only 0·11 ampère caused ignition. It should be noted that in the presence of high self-induction, it is more dangerous to break contact rapidly than slowly; this is due to the very great, but rapidly dissipated, tension of the extra current which is most active at a certain degree of rapidity of contact-breaking, but is not able to produce a long arc when contact is broken slowly. This result was confirmed in a lamp circuit worked by an alternating current which produces greater self-induction than a continuous current of equal strength; no ignition took place at 1·2 ampères with slow contact-breaking, while it occurred when contact was broken rapidly at 0·73 ampère (experiments Nos. 27-31).

The mercury switch for 50 ampères caused ignition in a lamp-circuit with 1 ampère.

All the switches tried thus produced ignitions with current-strengths very far below the normal strengths for which these switches were intended.

Short circuits from accumulators giving tensions of 4 to 8 volts could be interrupted safely at strengths of 20 to 25 ampères, and it made no difference whether the terminals used were of iron or copper (experiments Nos. 33-35).

The conclusion of all these results is: firstly, that the strength of the current alone forms no measure of the danger of the sparks produced; other things being equal, greater current-strength certainly increases the danger of the spark, but the other conditions of the current are quite as important as, or even more so than, its strength.

Next, the tension of the current has to be considered, as the possibility of the formation of a dangerous arc depends upon it. It is assumed that the smallest arc must possess a tension of at least 26 volts. Tension can be replaced, however, by self-induction, and the more completely because the tension of the extra current so many times exceeds that of the working current: this is the reason why with great self-induction the low strength of 0·11 ampère is already dangerous, and it is probable that this is by no means the minimum limit.

Further, the class of switch affects the degree of danger due to the spark produced by breaking contact. Multipolar switches designed for powerful currents, which distribute the spark between several points, are safer than the others ; in the same way, in normal circuits, rapid-action switches are safer than slow ones, though exceptions may arise when the circuit is liable to unusually high self-induction.

It therefore seems impossible to define the limits within which the sparks produced on breaking contact are or are not dangerous.

Experiments with Safety-fuses.—Fuses or fusible cut-outs are designed to interrupt the current by melting whenever the strength becomes excessive ; they are made for any required strength, and are usually arranged to fuse when the normal current-strength is exceeded by 100 per cent. They are usually made of lead, and when they fuse, a spark or an arc is formed, the latter being capable of lasting for some time. The power of this spark or arc varies greatly with the strength, tension and self-induction of the current.

The following 5 experiments, conducted in an explosive mixture of gas, show that in any case fuses, when not enclosed, are very dangerous. Even a high-tension cut-out caused ignition with a current of only 0·85 ampère (experiment No. 5).

Experiments Nos. 1, 2, and 3.—Leaden fuses for a normal strength of 4 ampères were fused by a continuous current with 100 volts tension, and caused ignition in each of three trials.

Experiment No. 4.—A leaden fuse for a normal current of 20 ampères was fused by a 110 volts alternating current, and caused ignition.

Experiment No. 5.—A high-tension leaden fuse for a normal current of 0·85 ampère was fuzed by a 100 volts continuous current, and caused ignition.

Experiments on Resistances.—Resistances are introduced into circuits before motors, in order that the whole power of the current shall not at once be allowed to act on the motor at starting ; they consist of a number of spirals of wire made of an alloy (manganin), which can be thrown into or out of the circuit gradually by means of a lever-switch and a series of contacts. There are three sources of danger in such resistance-coils according to their construction, due either to sparking at the contacts, to the overheating of the wire spirals or of carbon contacts if these are used. Experiments were accordingly directed to these three points, and the results are shown in Table V.

The sparks generated at the contacts are always slight, because the alterations of current-strength by shifting the lever from one contact to

TABLE V.—EXPERIMENTS ON RESISTANCES.

No. of Experiment.	Object Tested.	Maximum Current-Strength Employed.	Mode of Conducting the Experiment.	Result.	Observations.
			EXPERIMENTS ON SPARKS PRODUCED AT THE CONTACTS.		
1	Resistance for 4·13 ampères and 15 ohms	Ampères. 14–15	The current-strength was changed 80 times by shifting the lever along the contacts.	No ignition	No perceptible sparks.
2	„ „	20–25	„ 80 times „	„	„ „
3	„ „	30–35	„ 80 „ „	„	Sparks were noticed.
4	„ „	40–42	„ 60 „ „	„	„ „
5	„ „	80	The full current of 80 ampères was interrupted by means of the resistances.	Ignition	Strong spark.
			EXPERIMENTS ON GLOWING SPIRALS OF WIRE.		
6	Resistance for 4·13 ampères and 15 ohms	60–70	Four spirals of manganin wire, 0·1 inch in diameter, were brought to a red heat and kept so for 12 minutes.	No ignition	Resistance placed horizontally. On raising the heat further, the spirals bent and short-circuited; an arc formed, causing instant ignition.
7	„ „	60–70	„ for 5 minutes and coal-dust then suspended in the chamber.	„	Resistance standing upright.
			EXPERIMENTS ON GLOWING CARBON CONTACTS.		
8	Contact made between a rectangular rod of carbon 0·8 inch wide and a brush of copper wire weighted with 2 lbs. (875 grm.)	12–30	The carbon glowed at several points which shifted about, during 7 minutes.	No ignition	Carbon partly burnt away at termination of experiment.
9	„ „	30–40	„ but glow stronger and lasted for 9 minutes.	„	„ „
10	„ „	40–55	The contact glowing throughout its breadth for 4 minutes.	„	„ „
11	„ but unweighted ...	35–50	„ for 11 minutes, the carbon was red-hot near the contact and white-hot at some points.	„	„ „
12	Contact made between two carbon rods 0·8 inch broad, unweighted	36–50	The carbons became dark red, and in spots white-hot near the contact. Experiment lasted 12 minutes.	„	„ „

the next are only relatively small; as shown by the experiments (Nos. 1-4) the danger of igniting explosive gaseous mixtures by such sparks is very remote, given a moderate degree of intelligence in handling the resistance. Ignition was only produced upon breaking a current of 80 ampères (experiment No. 5) or about six times what the resistance was intended for.

Even wires raised to redness can hardly be considered a source of danger; in experiment No. 6 (Table V.) 4 wires 0·10 inch in diameter were kept at a bright red heat for 12 minutes without producing any ignition, although the explosive mixture was repeatedly set in motion by revolving the fan. The suggestion that possibly the fire-damp was rapidly decomposed by the glowing wires and the latter thus surrounded by a body of non-explosive gas, is inadmissible in view of the conclusion of the experiment, for as the spiral was not properly placed in a vertical position but lay horizontally, one of the coils bent down and met another, producing a small arc of light, followed by immediate explosion. In the next experiment (No. 7) coal-dust was suspended in the explosive mixture while the wires were red-hot, in order to determine whether the presence of dust increased the liability to ignition; here again, however, no ignition occurred. It may be added that so long-continued high temperature of the wires, as was purposely produced in the experiment, would be impossible in practice, as in this case the fuse would come into play and would melt through.

Finally, experiments Nos. 8-12 prove that heating of the contacts (of carbon either upon copper or upon carbon) is not a source of danger; in these experiments the highly heated contacts, points of which were raised up to whiteness, remained altogether 43 minutes in explosive atmospheres; the carbon even burnt away in part, on the sharp edge of the rods, without causing ignition.

Experiments with Continuous-current and Polyphase Motors.—The possibility of sparking from electric motors varies in degree according as these are either continuous-current or alternating and polyphase motors. All these motors act by the passage of electric currents through their armatures, which receive a torque through the influence of magnetic fields, and are thus capable of performing mechanical work. While continuous-current motors possess a fixed magnetic field and the necessary current must therefore be conveyed to the armatures by means of brushes and commutators, the armature-currents in alternating and polyphase motors are generated by induction, so that the armature may be wound with a closed circuit having no external connexion, as the magnetic field itself revolves and carries the armature with it. From this it is clear that continuous-current motors require brushes, and can therefore never be quite free from the objection of sparking. On the other hand, alternating and polyphase motors can be worked quite without sparks, provided that the armature-coils form closed circuits. This proviso is not always complied with. It is necessary to diminish as far as possible the resistance of the armature-coils in order to limit the heating and consequent loss of power; in consequence of this, if the full working current be suddenly sent into a motor at rest, the current induced in the armature-coils might easily become too strong and injure the machine. The more rapidly the armature is revolving the less is the strength of the current traversing its coils; hence, as a rule, it is not safe to turn on the full current until the motor is in motion.

This may be attained in several ways. The motor may be started simultaneously with the dynamo, when the current at first generated will not be too powerful and both machines gradually and simultaneously attain their normal speed and current-tension. This method can only be used when only one motor is in circuit with its corresponding dynamo, and is hence best suited for the transmission of power on a very large scale. In such cases, closed-circuit armatures are used, and no sparks can be formed. If, however, several motors are to be worked off one system with constant current, such armatures can be used only for the smallest motors (below ½ horsepower), as in these the armature-coils may possess a comparatively high resistance. In other cases, resistances must be introduced into the armature-circuit, so that these can be cut out as the speed increases. In these motors, the terminals of the three armature-coils are connected to brushes working on three rings attached to the shaft, by means of which the induced current can be conveyed to the resistances. Sparks can only be produced when the brushes are damaged or are not in close contact, and this danger may be easily guarded against by having a pair of brushes on each ring.

More recently a form of starter, introduced by Messrs. Siemens and Halske, has been used: in this, there is a second coil on the armature wound in the opposite direction, though with but few turns, which can be thrown out of circuit by hand, or automatically by centrifugal action when the speed rises sufficiently high. The production of sparks is here not impossible: it is, however, an easy matter to enclose the centrifugal cut-out perfectly air-tight.

The experiments performed with motors had reference only to continuous-current and polyphase machines. Alternating single-phase motors were not tested, because they are of little importance in mining, and because, moreover, their construction, so far as relates to their behaviour in explosive mixtures of fire-damp, does not differ from that of polyphase motors.

The first tests (Table VI.) were made with a small continuous-current motor of ½ horsepower for 110 volts, provided with carbon brushes; when the latter were so placed as to cause sparking, ignition occurred as soon as the motor was started in an explosive mixture (experiment No. 1). When the brushes were in their right place it was found that the small sparks produced during normal running caused no ignition, though the heavier sparks produced when the machine was started did so (experiments Nos. 2 and 3).

The experiments were repeated on a larger scale with a 6½ horsepower motor for 150 volts, the brushes being so placed as to cause as little sparking as possible. After the gases were introduced, the motor was started, and was repeatedly loaded up to 5½ horsepower by means of a lever-brake worked from outside the chamber by means of a rope. The slight sparks thus produced caused no ignition either with carbon or copper-wire brushes.

Polyphase motors gave very satisfactory results; three different forms were available, one with brushes and contact-rings, one with a hand cut-out, and the other with a centrifugal cut-out; their normal power was 5 horsepower with 110 volts and 27·6 ampères. The first-named was tested under conditions of special severity; whilst running under a load of 1½ horsepower, one of the brushes was lifted off its ring 30 times by means of a cord; although tiny sparks were visible, no ignition was produced.

When the resistances were cut out in the motor worked by hand, stronger sparks were seen, so that ignition appeared probable; even, however. with a load of 3½ horsepower, the highest it was possible to employ, 150 trials caused no ignition (experiment No. 7). This may possibly be explained by the strong air-current that sweeps past the points where the sparks form.

Experiment No. 8 with the motor provided with centrifugal cut-out enclosed air-tight gave, as might be expected, no ignition.

Experiments with Igniters.—Three types of electric igniters are employed in Westphalia, namely:—

1. The frictional electric machine of Messrs. Bornhardt of Brunswick or of the Nobel Dynamite Company in Vienna.

[illegible]

[illegible]	Continuous-current motor, shunt-wound	150	37	[illegible]	[illegible]
5	” ” ”	150	37	Same experiment, with copper brushes. [illegible] experiment [illegible] lasted 10 minutes.	”
6	Polyphase motor with resistances, 5 horsepower. Mark, *D M 10/10.*	110	27·6	Started with a light load in an explosive mixture, and run for 5 minutes. Then one of the brushes was lifted 30 times under a load of 1¼ horsepower, producing slight sparks.	”
7	Same machine, with coil and hand cut-out	110	27·6	Started with a load of 3½ horsepower in an explosive mixture, and run for 15 minutes, during which the coil was cut out and thrown in 150 times. Sparks were formed.	”
8	Same machine, with centrifugal cut-out	110	27·6	Started without load in an explosive mixture, and run for 20 minutes, during which the centrifugal cut-out was brought into operation 20 times by abrupt variations of current.	”

2. The low-tension machine of Messrs. Siemens and Halske of Berlin.

3. The machine of the Roburite Company of Witten-on-the-Ruhr for spark-ignition (high tension).

In the machines included under class 1, the electricity generated in a friction-machine is collected in a Leyden jar, which is discharged with a spark when ignition is produced, the tension being at least several thousand volts. It is wellknown that such machines can cause ignition of fire-damp by the sparks leaping between badly arranged conductors; the experiments were therefore only directed towards finding out whether the smallest of such sparks could cause ignition. A Nobel machine intended for 15 shots was employed, and it was found that sparks less than 0·02 inch in length were safe, but that a spark 0·04 inch in length would cause ignition.

The machines under classes 2 and 3 are magneto-electric machines producing alternating currents; those under class 2 heat a small platinum wire, and those under class 3 a mixture containing graphite-powder, to redness inside the detonator and thus determine the explosion. As the conductivities of platinum wire and graphite-powder are widely different the armatures of the machines have very different resistances produced by the methods of winding, and produce currents at very different tensions, as shown by the following table:—

Description of Machine.	Shots to be Fired Simultaneously. No.	Tension of Current Produced. Volts.	Internal Resistance of the Armature. Ohms.
Siemens and Halske, low tension ...	1 ...	6 ...	0·8
" " ...	2 ...	14 ...	3·1
" " ...	10 ...	34 ...	4·5
Roburite Company, high tension ...	1 ...	61 ...	292
Similar English machine ...	Several (exact No. unknown)	90 ...	980

At the low tension of these machines it is impossible for sparks to form when contact is made, such sparks requiring a tension of at least 500 volts. Sparks can only be produced exceptionally when the circuit is interrupted and contact broken. Although such sparks can but rarely be formed, some experiments had already been made upon their danger in explosive mixtures and have been repeated here. It was found that the first machine on the above list, having a tension of 6 volts, is safe, but that the sparks produced on breaking the circuit of the other machines could ignite explosive mixtures both at rest and in motion. This result is probably due to self-induction, and serves rather to show the danger that may in certain circumstances attend slight sparks than to afford any indication of the danger of electric igniters in general.

There is, moreover, an easy means of greatly diminishing or quite overcoming whatever danger may attend the use of the machines in question. If the terminal screws of the machine are united by a thin spiral of German-silver wire, the efficiency of the igniter is scarcely affected, as practically the whole of the current generated continues to flow in the considerably less resistant outer circuit; and when the latter is broken the dangerous extra current passes harmlessly through the short-circuiting spiral. The Roburite Company's small igniter was thus furnished with a spiral of German silver of 1,500 ohms resistance; its efficiency was not perceptibly diminished, but it was now found impossible to ignite explosive gas with the very small sparks that could alone be produced. These spirals are easily placed inside the machine. According to a communication from the Roburite Company, all their present machines are being provided with such a safety-spiral.

Miscellaneous Experiments.—Glowing wires, which have already in part been considered under resistances, were found to be comparatively safe in explosive mixtures, except in the case in which a spark is formed by interruption of the circuit by melting of the wire. Iron wire must possess considerable thickness, and be heated to nearly its melting-point if ignition is to be produced. Only in a single case (experiment No. 1, Table VII.) could it be asserted with certainty that the gas was ignited before the iron wire (0·027 inch in diameter) was melted. In experiments Nos. 2, 3, 7 and 8, the melting of the wire and the ignition of the gaseous mixture coincided so closely that ignition seemed to be due to the spark formed by breaking the circuit. Experiments Nos. 4, 5 and 6, in which two iron wires, 0·016 inch thick, of different lengths were in circuit in parallel, are noteworthy; the object of this arrangement wss to diminish as far as possible the spark produced when the shorter wire which was first raised to the melting-point was fused through. In these cases, the shorter wire could be fused without igniting the explosive mixture. Copper wire when fused through, ignited the gas owing to the spark produced on breaking circuit.

Electric Arc embedded in Coal-dust.—Experiments with arc-lamps had already shown that powerful arcs were incapable of igniting suspended coal-dust; it was still doubtful how an arc in direct contact with coal-dust would behave. An iron wire, 0·053 inch in diameter and 8 inches long, was therefore embedded for its whole length, 0·4 to 0·8 inch deep in coal-dust, and was then heated to whiteness and burnt through

TABLE VII.—EXPERIMENTS WITH GLOWING WIRES IN EXPLOSIVE MIXTURES.

No. of Experiment.	No. and Material of Wires.	Diameter of Wire.	Length of Wire.	Current Strength.	Mode of Conducting the Experiment.	Results and Observations.
		Inch.	Inches.	Ampères.		
1	1 iron wire ...	0·027	40	25	Wire caused to glow by continuous current from dynamo	Ignition when wire reached white heat; wire burnt through after ignition.
2	1 iron wire ...	0·027	40	25-30	,, ,,	Ignition appeared to occur just as the wire burnt through.
3	1 iron wire ...	0·016	40	7	,, ,,	Ignition occurred when the wire burnt through.
4	2 iron wires ...	0·016 0·016	40 320	7-10	,, but with 2 wires in parallel	No ignition, although the shorter wire burnt through.
5	2 iron wires ...	0·016 0·016	40 320	7-10	,, ,,	,, ,,
6	2 iron wires ...	0·016 0·016	40 320	7-10	,, ,,	,, ,,
7	2 iron wires ...	0·016 0·043	40 40	Not observed	,, ,,	Ignition as both wires burnt through, which occurred almost or quite simultaneously.
8	2 iron wires ...	0·043 0·043	40 400	50	,, ,,	Ignition when the shorter wire burnt through, after it had remained for some 2 minutes at a strong yellow heat in the mixture without igniting it.
9	1 copper wire...	0·021	40	31	As in experiment 1	Ignition occurred when the wire burnt through.

by an electric current. A long and powerful arc was thus produced, which ignited the dust round about it to a bright flame, which it maintained steadily; meanwhile coal-dust was repeatedly suspended above the flame, but the flame did not spread into this dusty atmosphere, nor was any explosion produced. Fire-damp was not employed in this experiment.

Protection of Motors by Wire-gauze.—Experiments were made with the above described small continuous-current motor enclosed in a box, the top of which was formed of a fine wire-gauze of about 55 meshes to the linear inch (500 to 1 square centimetre), but no definite results were obtained. After the box had stood a considerable time in an explosive mixture, so that diffusion might be assumed to have taken place, the motor was so started as to produce sparks. The gaseous mixture ignited on that side of the box which contained the commutator, but the flame only rose upwards without traversing the gauze, and did not extend over the whole box. The experiment was repeated in the same way 12 or 15 times, always with the same results. Several times the flame lasted for a few moments, and was evidently fed by a current of gases from the other end of the box, but no approach to an explosion could be produced. At the close of the experiment, the wire-gauze showed that it had really been exposed to heat only just above the commutator.

The Sparks of an Electric Gas-lighter, constructed like a small influence-machine, which is much used for lighting ordinary coal gas, were found incapable of igniting fire-damp; the sparks produced by it were 0·12 to 0·16 inch long.

Conclusions and Precautions.—It must first be pointed out that the above experiments had neither the object nor were they capable of formulating a definite opinion as to the applicability of electricity in fiery mines; the results of the investigations merely furnish a foundation for future studies which will have to be extended in many directions.

Manufacturers of electrical machinery will have to make use of the experience gained in order to produce safer forms of machines, and experiments upon these newer patterns will then have to be continued.

In brief, the sum of the results obtained show that in general the amount of electrical energy which is capable under certain circumstances of igniting fire-damp need only be extremely small. This amount cannot be definitely fixed, however, as it depends not only on the quantity of energy but on the mode of its application and other attendant circumstances. It is only in the case of a current, the conditions of which are exactly known, that quantitative statements can be made as to the limits of safety for certain classes of transformation of energy. In any case, all visible sparks may be looked upon as dangerous. Experiment alone can decide whether certain classes of sparks may be devoid of danger.

Explosions of coal-dust alone appear to be impossible of production by electricity, unless indeed specially dangerous classes of coal-dust behave differently from those tried.

As regards particular appliances, the following conclusions appear justified :—

Portable incandescent lamps (with accumulators) must be protected as far as possible against fracture of the bulb. Appliances that interrupt the current when the bulb receives a push or a blow are useful and desirable. Sparks produced when such lamps are thrown out of circuit are free from danger.

For the illumination of galleries underground by means of fixed incandescent lamps, lamps of high voltage and not exceeding 0·5 to 0·6 ampère current strength are to be recommended. Care must be taken that the wires to which the carbon filament is secured shall project as short a distance as possible into the lamp, so that they cannot come into contact and cause short-circuiting should the bulb break. The use of two filaments in a bulb is not advisable, as the danger of short-circuiting is thus increased. For the same reason, a tension exceeding 150 volts appears inadmissible for the present. Every lamp should be protected by an outer cover of thick glass, so that the preservation of the filament intact when the lamp is broken by external violence is out of the question. The spark produced by switching out a lamp in a circuit with not more than 0·5 to 0·6 ampère current-strength and free from any unusual amount of self-induction presents no danger.

If the above precautions are observed, a well laid out system of illumination by means of fixed incandescent lamps of high voltage would seem to be the safest of all ways of lighting the fiery parts of a mine. Possibly in the future, when such systems have been introduced underground, even the most remote though specially dangerous points, such as the working-faces, may be lit in this way.

Arc-lamps must not be used in fiery mines. All switches, with the exception of the special cases indicated above, and all safety-fuses, must be enclosed so as to prevent the transmission of flame.

In resistances, those parts in which visible sparks may form must be enclosed. The heating and even occasional glowing of the wire spirals is devoid of danger, although care must be taken that the wires are not insulated with combustible materials.

Small continuous-current motors may easily give rise to ignitions due to sparking at the commutators. Larger motors, in perfect order, with intelligent handling and in normal working, are safe, even although sparks are not entirely avoidable. These conditions are, however, so rarely fulfilled in working underground that it seems preferable to enclose either the entire motor or those parts of it that produce sparks in a flame-proof casing.

Polyphase motors with short-circuited armature coils, or with contact-rings with a pair of brushes on each, or with centrifugal cut-outs enclosed air-tight, give no sparks in ordinary working, and are devoid of danger. The hand cut-out device seems more open to objection on account of the inevitable production of sparks, although in the experiments no ignition was produced with such a motor.

Electric shot-firing with frictional machines is only dangerous when the leads are carelessly laid. Ordinary high- and low-tension shot-firing is quite free from danger, provided the precautions previously explained are observed.

The authors wish to add that these experiments on the effect of electrical phenomena upon fire-damp will probably be continued. Makers of electric apparatus who wish to take part in future trials are requested to communicate their wishes and suggestions, or details of new appliances that they would like tested, to the authors.

The following paper by Mr. G. LITTLE was read on "The Automatic Manipulation of Coal and Coke"* :—

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* This paper was read at the Birmingham Meeting on September 23rd, 1898.

THE AUTOMATIC MANIPULATION OF COAL AND COKE.

By GILBERT LITTLE.

In this paper, the writer will not refer to any of the appliances used in the automatic manipulation of materials of every kind, but he will confine his notes to systems of machinery dealing economically with the loading, distribution and cleaning of coal and coke; as the cheap and efficient handling of these two articles of commerce is of special interest to the members of this Institution.

(1) In an automatic coal-store, the coal is brought in waggons from the railway-siding to a traversing-conveyor, which trims and stacks the coal over any part of the yard. The arrangement was applied to a large electric-lighting station, with a range of 28 double-flued boilers; but it could be easily modified to deal in a similar way with the coal for a battery of coke-ovens, rows of furnaces, or a bench of gas-retorts. It could also be modified and altered so that the traversing-conveyor could be fixed at any desirable height above the waggon, and the coal from the waggon lifted to the elevated conveyor by means of an elevator. In this arrangement, the discharge of the coal is regulated by means of the outlet-doors; and the conveyor is arranged so that it can be moved longitudinally along the yard: the distance of travel being limited only by the length of the storage-yard. The necessary power to work and control the traversing-conveyor is obtained from the small engine of the grab mounted upon the girder of the conveyor; and the grab-carriage is arranged to move on rails along the conveyor. The object of this arrangement is to keep the coal within range of the grab; but the grab is brought into use only when it is necessary to lift part of the reserve coal into the conveyor. The method of feeding the 28 boilers is to utilize the grab on as few occasions as possible, and for this object the coal is carried direct from the waggons by the conveyor as each supply comes into the works, and delivered at the end of the yard immediately over the boot of the elevator. The fuel for the boilers is taken from that part, except when the supply runs short, and then the grab is brought into use to lift the stored coal from the yard and deliver it into the con-

veyor, which in turn shoots it into the part over the elevator-boot, and thence, by means of the elevator, to the conveyor, which distributes it into each of the 56 hoppers of the mechanical stokers on the 28 boilers. At the foot of the elevator-boot, a door is fitted to prevent the coal from choking; and this door is operated by a self-acting arrangement from the driving-shaft of the elevator, so that the quantity of coal allowed to pass into the boot is controlled by the speed of the buckets. The correct quantity only is admitted, and thus all risk of a stoppage is obviated.

(2) An arrangement of elevators and conveyors is used for unloading coal from a barge on a canal or river, and distributing it over a coal-store or a coal-yard. The elevator is made with a dust-tight casing, so as to prevent dust blowing about from an elevator fixed in this open manner. The barge-elevator is raised or lowered as may be necessary to suit the rise and fall of the water or tide, by means of compensating balance-weights. The elevator, unloading the barge, lifts and delivers the coal into the telescopic shoot, which in turn feeds the small hoppers over the boot of the stationary elevator; and the stationary elevator lifts the coal and delivers it into the conveyor, which in turn trims or discharges it at any part of the coal-store or yard.

(3) A combined portable elevator and conveyor is used to trim coal or stack it all over a yard. The coal is shot from the waggons into the hopper of the elevator-boot, and the elevator lifts it into the traversing-conveyor, which in turn trims it over the yard. The traversing-conveyor can be made of any desired width, to suit any size of yard. The superstructure is light and simple; and the power can be transmitted to the elevator and conveyor by means of a rope or detaching-shaft. This form of conveyor can also be made to take to pieces, for removal from one part of a works to another, when it is not convenient to continue an unbroken line of rails all round those parts of the works where the coal can be stored.

The writer could have described to the members numerous arrangements for unloading and distributing coal, but the three described will suggest others to the inventive minds of the members of this Institution.

(4) The Chesterton chemical-works are arranged like the retort-house of a gas-works, making high-class coke and chemical bye-products only from the coal. The conveyors are fixed in front of the benches of retorts, and the coke is carried from each bench of retorts by two conveyors. These, in turn, shoot the coke into a conveyor fixed at right angles, which

carries it to the railway-waggons. The shoot, conducting the coke from this conveyor to the railway-waggons, is made with screen-bars, which separate the breeze, and discharge it into the breeze-barrow.

(5) At one of the Gas Light, Coke and Coal Company's works in East London, the retort-house is over 300 feet long, with two double benches, containing 200 retorts. Four conveyors run along the front of the four rows of the mouthpieces of the retorts, and carry the coke to the conveyors at the end of the retort-house, which in turn deliver it to the elevator. The elevator drops the coke on to the conveyor fixed above; and this trims it over the storage-hoppers. Measuring-chambers are fixed on the bottom of the storage-hoppers from which the sacks are filled.

(6) At a new-retort house in Jersey, the coke is conveyed along the front of the benches under the cartway; and, passing through the coke-breaker, it is elevated to the hopper above. The delivery-shoot of the elevator is made with a deflecting valve, by means of which part of the coke is delivered into the hopper and part into the conveyor, to be delivered on the coke-stack; or all of the coke can be delivered into the hopper or on to the coke-stack. Under the large storage-hopper, a small hopper is arranged to deliver a certain weight of coke into the carts. The cart is brought under the hopper, the carter pulls the lever, and away he goes with his proper load within a minute.

The writer trusts that these descriptions of arrangements of coke-elevators and conveyors may be helpful to members in setting out like plant at ranges of coke-ovens.

(7) At the screening-plant at the Fochriw pit of the Dowlais Iron Company, the tubs are taken by a double-chain creeper to the top, and run down a gradient to two tipplers, in which the coal is automatically tipped on to large fixed screens, fitted at the end with a jigger to trim the large coal upon two wide picking-belts; while the various smaller sizes have passed through the screen-bars into "billy-fairplay" boxes, and are weighed and delivered into conveyors, which carry the smaller sizes to trucks on the different lines of rails. The ends of the two wide picking-belts are arranged with lowering jib-ends so as to obviate breakage of the large coal.

(8) The screening and cleaning-plant at one of the Brymbo collieries is similar to that just described, but of a lighter style of manufacture, suitable to the smaller tubs in use and smaller coal obtained in the district. The tubs run from the pit-mouth down an incline to turn-

tables, and are delivered to either of the tipplers. The empty tubs return by means of a short incline to the creepers, and thence to the cage-level.

(9) At the screening and picking-plant at the Usworth colliery, Durham, the full tubs run from the cage by gravitation to the tipplers, and are returned by means of a very steep creeper. This plant has been arranged to suit local requirements, and is somewhat similar to that at the Brymbo collieries, except the absence of the dipping-ends on the picking-belts, a hinged delivery-shoot being used to conduct the coal from the picking-belts to the waggons. The picking-belts are 4½ feet wide, with a channel in the centre, into which the attendants throw the shale, dirt, stones, etc., which are collected and carried away by a conveyor.

The writer has given the very briefest possible description of the machinery, without describing the details of the manner in which the creepers, tipplers, screens, jiggers, picking-belts, or conveyors are constructed.

Mr. Roslyn Holliday (Pontefract) referred to the difficulty of obtaining a conveyer which would stand the wear and tear of hot and wet coke.

Mr. M. H. Mills (Mansfield) was of opinion that the only advantage of the appliances described was in the saving of labour.

The Chairman (Mr. G. Lewis) remarked that he did not quite concur with Mr. Mills that the described appliances only effected a saving of labour. In the olden days, two men with picks were employed in taking the large lumps of coal out of one tub. The present methods of manipulating coal effected not only a saving of labour, but they enabled the workmen to pick out the different sorts required. In fact, the manipulation process had enabled a considerable number of coal mines, which at one time were not considered worth working, by means of automatic screening, to put their coal on the market and dispose of it at remunerative prices. He had pleasure in proposing a vote of thanks to Mr. Little for his interesting paper.

The motion was agreed to.

Mr. John Nevin moved that the thanks of the members be accorded to the North Staffordshire Institute of Mining and Mechanical Engineers, to Colonel Strick, C.B., and the officers of the First Shropshire and Staffordshire Artillery Volunteers for the use of their large hall, and to Messrs. F. Winkle & Co., Messrs. Minton & Co., the

Birchenwood Coal Co., and to the Sneyd Collieries and Brickworks Co. for having opened their works and collieries to the inspection of members.

The **President** seconded the motion, which was cordially adopted.

Colonel **John Strick** responded on behalf of himself and brother officers.

Mr. J. C. **Cadman** (Newcastle-under-Lyme) moved that a vote of thanks be given to Mr. J. A. Longden for his services in the chair, and the resolution was cordially adopted.

The following notes record some of the features of interest seen by the visitors to collieries and works, etc., which were, by kind permission of the owners, open for inspection during the course of the North Staffordshire meeting on February 22nd and 23rd, 1899 :—

SNEYD COLLIERY AND BRICKWORKS.

There are three shafts at present at work, and known respectively as Nos. 1, 2 and 3. No. 1 shaft is not used for winding, but serves as the upcast for Nos. 2 and 3 shafts. No. 2 shaft is sunk to a depth of 1,959 feet, but the inset is situated at a depth of 1,863 feet, the lower portion being partly filled up, in consequence of the disturbance caused by a large fault of 300 feet throw which intersects the shaft. No. 3 shaft is winding from a depth of 1,113 feet.

The Mossfield (below fault), Main, Bowling Alley, Holly Lane and Hard Mine coal-seams are wrought at No. 2 shaft. The Burnwood coal and ironstone (below fault), and Seven-feet and Mossfield (above fault) coal-seams are worked at No. 3 shaft. The Holly Lane and Mossfield coal-seams furnish a high-class house fuel, the Bowling Alley and Main seams a second-class house and pottery manufacturing-coal, and the Hard Mine and Seven-feet seams steam- or furnace-coal.

Special interest attaches to the Holly Lane workings, as, owing to the small thickness of the seam (barely 3 feet), a novel form of working by means of "spunneys" has been adopted.*

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* *Trans. Inst. M.E.*, vol. ix., page 226.

The dip of the strata is 1 in 4 towards the west. A large fault of 300 feet downthrow to the west, already mentioned as intersecting the No. 2 shaft, traverses the estate from north to south.

Steam is supplied from 6 Lancashire boilers, 7 feet in diameter, and 2 additional boilers are now being installed, 8 feet in diameter by 30 feet long, in order to cope with the additional power required for sinking a new shaft to a depth of 2,700 feet and the sinking of No. 3 shaft to the same depth. The working pressure is 80 pounds per square inch.

The winding-engine at the No. 2 Pit is of the compound-condensing horizontal type, consisting of high and low-pressure tandem cylinders placed on each side of the drum. The main dimensions are—high-pressure cylinders 36 inches in diameter, and low-pressure cylinders 51 inches in diameter by 6 feet stroke. This engine is fitted with steam-reversing gear, and Woodworth progressive cut-off gear, by means of which the period of steam-admission is slightly reduced at each successive stroke.* The air-pumps are worked by independent engines.

At the No. 3 Pit, the Kœpe system of winding is in operation. The winding-engine has two cylinders, each 16 inches in diameter by 4 feet stroke.

The railway-sidings are extensive, and serve the brickworks in addition to the colliery. They are connected to the North Staffordshire Loop Line Railway.

There are 5 screens of the shaker type, with picking-belts to accommodate the various classes of coal. The tipplers are of the Heath and Woodworth pattern with positive driving.†

The surface and the main roads underground are lighted by electricity, the current being derived from 2 Crompton dynamos, each having an output of 140 ampères and 112 volts, at a speed of 350 revolutions per minute. The dynamos are direct driven by high-speed Robey engines. This type of plant has proved highly satisfactory, as after 5 years' running the machines are in good condition and the commutators have never required re-turning. In addition to lighting, the current is utilized for working 2 motors on the surface.

All the safety-lamps are of the bonneted Mueseler type, fitted with the Heath and Frost burner for utilizing petroleum.

A plant has recently been erected, for utilizing the dirt-heaps, consisting of a pan (9 feet in diameter) for grinding the raw material, which is then delivered by means of an elevator to a stiff-plastic brick-machine capable of turning out 10,000 bricks per day. The green bricks are taken direct to the kiln, which is of the continuous type with 14 chambers. The glazed and firebrick works lie about ½ mile from the colliery on the western side of the North Staffordshire Railway. The glazed bricks are of high quality, and were selected by H.M. Commissioners of Works for use at Windsor Castle and other public buildings. The company are also makers of salt-glazed and firebricks, quarries, boiler-seating blocks, etc.

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* *Trans. Inst. M.E.*, vol. x., page 470.

† *Ibid.*, vol. ix., page 231.

BIRCHENWOOD COLLIERIES.

The members visited the Birchenwood collieries, where the lower coal-seams of the North Staffordshire District are being worked. Considerable extensions have recently been made; the machinery comprises large compound air compressor, coal-washer capable of washing 1,000 tons per day, modern coke-ovens, boilers fired with waste-gases from ovens, etc.

HATTON WATERWORKS OF THE STAFFORDSHIRE POTTERIES WATERWORKS COMPANY.*

The Hatton pumping-station is situate about 6 miles south-west of Stoke-upon-Trent and 1¼ miles north of Standon Bridge Station, on the London and North-Western Railway. The machinery consists of two compound vertical beam engines, with surface condensers, the high-pressure cylinders are 32½ inches in diameter by 54 inches stroke, and the low-pressure cylinders are 48 inches in diameter by 84 inches stroke, each capable of raising 1,500,000 gallons of water per day, against a head of 500 feet. Two 12 inches boreholes have been put down to a depth of 500 feet in the New Red Sandstone. The well or pumping shaft is 100 feet deep, and 15 feet in diameter,

An additional pumping plant is now being erected at the pumping-station.

The covered service reservoir is constructed in cement concrete; it is 215 feet long, 155½ feet broad and 15 feet deep, with a capacity of 3,000,000 gallons.

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* *Trans. Inst. M.E.*, vol. viii., pages 69 and 71.

EXPERIMENTAL INVESTIGATIONS UPON THE THEORY OF THE PITOT TUBE AND THE WOLTMANN MILL.[*]

BY A. RATEAU, MINING ENGINEER, PROFESSOR AT THE SCHOOL OF MINES, ST. ETIENNE.

INTRODUCTION.

The Pitot tube[†] and Woltmann mill[‡] are frequently employed by hydraulic and mining engineers to measure the rate of flow of currents of air and water. It is, therefore, important to know whether these instruments give accurate measurements, and if not, what is the degree of approximation which may be relied upon under the different conditions in which they are employed, as also the causes that might affect this accuracy. Up to the present, however, there are but few data as regards this somewhat obscure subject.

Some experiments which the author has made to throw light upon it led to conclusions partly new, which allow of the cases being defined in which measurements made with the Pitot tube and with anemometers can be looked upon as accurate. They also show closely the causes which lead to inaccurate measurements in the majority of cases.

Some engineers look upon the Pitot tube as an invariably accurate instrument, and hold that if, when immersed in a current of fluid, it indicates a certain height of dynamic pressure h, estimated in terms of the column of fluid experimented upon, the velocity v of the fluid is related to h, as indicated by the wellknown equation :—

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[*] Translated by Prof. Henry Louis, M.A., A.R.S.M., from the *Annales des Mines*, 1898, series 9, vol. xiii., page 331.

[†] Suggested by Pitot, geometer and engineer, in 1732, to gauge the rate of currents of water. It was improved by Mr. Darcy, who added, in 1856, the straight tube to indicate static pressure (Dijon fountain).

[‡] This was suggested by Mr. Reinhard Woltmann, hydraulic engineer (died at Hamburg in 1837), whose first publication on this subject, entitled *Théorie et Emploi du Moulinet Hydrométrique* (Theory and Use of the Hydrometric Mill), is dated 1790.

The Woltmann mill was afterwards employed as an anemometer in 1820 by Mr. Kallstenius (*Archiv für Bergbau und Hüttenwesen*, vol. v.), and, in 1837, by Mr. Charles Combes, who explained its theory and showed how it should be calibrated in a work, "Sur un nouvel Anémometre (On a New Anemometer)," inserted in the *Annales des Mines*, 1838, third series, vol. xiii., page 103.

Mill-shaped anemometers had already been employed in the previous century, as indicated in the work of Jacques Leupold, *Théâtre universel des Machines et des Sciences Mécaniques;* Leipzig, 1724.

$$h = \frac{v^2}{2g}, \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (1)$$

g being the constant of gravity.

Others again consider that this relation does not agree with the observed facts, but that it may be brought into accordance with them by multiplying the second member, $\frac{v^2}{2g}$, by the factor a, the value of which is approximately 1·15, so that we should have :—

$$h = a\,\frac{v^2}{2g}, \text{ when } a = 1{\cdot}15. \quad . \; . \; . \; . \; . \; . \quad (2)$$

It will be proved in the sequel that both may be right in particular cases, but not generally, the coefficient a being variable, and even widely variable, according to circumstances.

As regards mill-anemometers, the researches of Messrs. Aguillon, Fumat and Murgue[*] have shown that when they are applied to the measurement of air-currents they give results which are generally too high.

The Prussian Fire-damp Commission has also made tests which verify this important discovery.[†] Up to the present, however, the limits within which this exaggeration of velocity may occur, are unknown, neither is it known to what causes it is to be attributed, nor whether it is possible to get rid of it. The author has already shown that in certain cases it is slight.[‡]

Further on, it will be established that this exaggeration is due to the inertia of the instrument, and is only produced in currents the velocity of which varies rapidly. The Dubuat paradox, to which the phenomenon in question has been attributed, appears to have but a very remote connexion with it.

Finally, the author proposes to show in the third part that the formula generally adopted for hydrometers and anemometers :—

$$v = a + bn \quad . \; . \; . \; . \; . \; . \; . \; . \quad (3)$$

a and b being two constants, and n the number of revolutions of the instrument per second, may for exact measurements be replaced with advantage by another formula having the form :—

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[*] *Bulletin de la Société de l'Industrie Minérale*, 1878, second series, vol. vii., page 505.

[†] *Ibid.*, 1889, third series, vol. iii., page 402 *et seq.*

[‡] *Ibid.*, 1892, third series, vol. vi., page 212.

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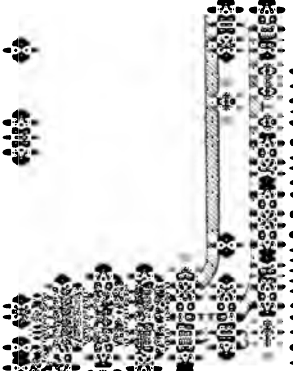

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in a vessel, A (Fig. 2), is
by a regularly convergent

nozzle, B. The static pressure in the vessel, A, which is sufficiently large to enable the velocity of air in it to be neglected, is measured by means of a water-gauge, C, in which *mn* is the column of pressure. On the other hand, the total pressure in the jet escaping through the orifice is measured by means of a Pitot tube, T, and a water-gauge, D; and let *pq* be the column due to this pressure.

If the Pitot tube be an exact instrument, these two columns should be equal, or at least *pq* should be a trifle less than *mn*, on account of the slight loss of energy due to the friction of the air against the orifice. This is exactly what the experiment shews. The plane of the orifice may even be inclined decidedly to its normal position, without the pressure in the tube undergoing any appreciable change. For example, in one experiment *mn* was equal to 160 millimetres, and *pq* equal to 159 millimetres. This remarkable agreement appears to prove that:—

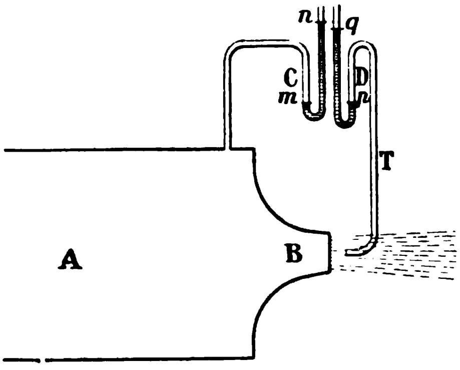

FIG. 2.

1. The Pitot tube indicates a total pressure equal to the static pressure, plus the height of the dynamic pressure,

$$h = \frac{v^2}{2g}.$$

2. The loss of energy by friction in the orifice is, in the case of air, very slight, and less than 1 per cent.; consequently the loss of velocity is less than 0·5 per cent.

One may therefore have confidence in the Pitot tube when the conditions are analogous to those just indicated; that is to say, when the current is perfectly regular.[*]

The velocity v is deduced from formula (1) $h = \frac{v^2}{2g}$, in which h is the difference between the height of the total pressure measured in the Pitot tube and the height of the static pressure measured in the straight tube. This difference may be obtained directly by means of

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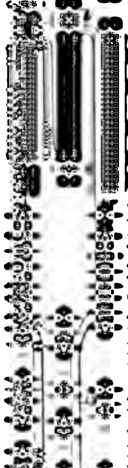
[*] This is also shown in the old experiments of Messrs. Dubuat and of Savart with jets of water, and the more recent experiments of Mr. Ch. Ritter (*Annales des Ponts et Chaussées, Mémoires et Documents*, 1885, vol. ix., page 1058).

tube (Fig. 3), one of the
ght tube, A, showing the
the Pitot tube, B.

he end of the straight tube
ge on the side facing the
y the tube from interfering
t of the mouth of the tube.
not extend below the plane
this plane is parallel to the
he pressure is exactly equal
in the fluid at the point in
is inserted. This can be
ng the tube A alone in the
the converging orifice of
tance from the last section
is cylindrical, the currents
wellknown that this causes
every part of the stream
surrounding pressure. The
the air, should therefore
d this is what experiment



ger be the case if the guard-
d. One would then find a
the true pressure, and this
with any inclination of the
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is necessary to satisify is
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found that the Pitot tube is
uid currents are irregular :
rtices which are constantly
d particles, wherefore the
between limits which may

., page 363.

"Flow, in even the most regular channel, is an exceedingly complex phenomenon. The mass of the current is continually being traversed by gyratory movements which intermix the different layers. At first sight, everything appears to be confused and irregular; but this disorder is only apparent, and if the mean of the successive velocities in each point of the section are calculated even for a somewhat short time, precise laws are soon found to rule. These means have a perfectly determined value, about which the velocities at each moment oscillate with a kind of periodicity."*

There is, therefore, in every point a mean local velocity.† It is this mean velocity which ought to enter into the expression of the quantity of flow, and which has accordingly to be measured. Can the Pitot tube show it by the same formula as before, or must a coefficient a (formula 2) be introduced, and how great will this coefficient be? This is an important question to solve. The experiment that the author is now about to record allows us to reply that it is necessary to introduce a coefficient a greater than unity. This coefficient is variable, and is the farther removed from unity the more irregular the current is. It may even be necessary at times to raise it to a value considerably greater than that of 1·15, which is usually adopted by hydraulic engineers.

In order to act upon the Pitot tube by a current of velocities varying in accordance with some known law, the author has arranged so as to plunge it successively, and at very short intervals, into two regular homogeneous currents flowing side by side. For this purpose a vessel, AB (Fig. 4), has been divided by a longitudinal septum, MN, into two compartments, A and B, in which, by means of a fan and valves, it is possible to maintain determinate pressures differing as widely as might be desired from one another. The air escapes from these compartments by means of orifices regularly convergent, so that two fluid streams a and b, were obtained side by side, up to within a

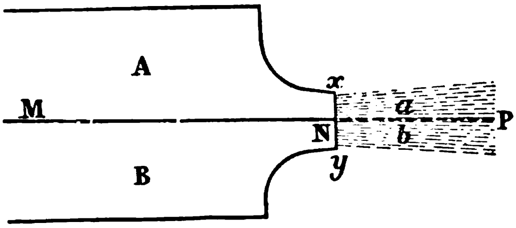

FIG. 4.

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* Mr. Bazin, "Note sur la Mesure des Vitesses à l'Aide du Tube jaugeur (Note on the Measurement of Velocities by means of the Gauge-tube)," *Annales des Ponts et Chaussées, Mémoires et Documents*, 1887, vol. xiii., page 227.

† Mr. Boussinesq, *Essai sur la Théorie des Eaux Courantes* (Essay on the Theory of Running Waters).

small distance from the orifices, x and y, and such that the velocity was quite constant in each of them, whilst the static pressure was always equal to that of the surrounding atmosphere.

Permanent rates of flow being established, the Pitot tube was first employed to measure the dynamic pressure in each of the two currents separately. The tube was then made to oscillate by a pendulous movement from one current to the next, in such a way as to remain sensibly equal times in each. This pendulous movement was obtained by means of a crank attached at one end to the tube, and at the other to a small handle, which the author could turn more or less rapidly.

As regards the tube, the effect was obviously the same as though it had been at rest, and had received alternately for two periods two air-currents with different velocities, v_1 and v_2, these velocities being known. It was therefore easy to compare the mean velocity (equal to one-half the sum of the two velocities v_1 and v_2) to the observed dynamic pressure. In adjusting the apparatus, care was naturally taken to see that the tube remained an equal time in each of the two currents.

When the handle was turned slowly, the column of the manometer was seen to oscillate, but when a velocity of two or three revolutions per second was attained, if care was taken to check the oscillations of the manometer by contracting the tube which unites the two branches, the column remained fixed, and could be read to ½ millimetre.

The following table gives an example of the results thus obtained :—Column No. 1 is the number of each experiment. Column No. 2 indicates the dynamic pressure h_1 in the current a. Column No. 3 indicates the dynamic pressure h_2 in the current b. Column No. 4 indicates the dynamic pressure h obtained by plunging the tube an equal time into each of the two currents. Column No. 5 gives the mean of the pressures in a and b.

No. of Experiment. 1	h_1. 2	h_2. 3	h. 4	$\frac{h_1 + h_2}{2}$. 5
	mm.	mm.	mm.	mm.
1	88·0	57·0	72·0	72·5
2	81·0	35·0	58·0	58·0
3	88·5	39·0	64·0	63·7
4	85·0	25·0	55·0	55·0
5	82·5	16·0	49·0	49·5
6	82·5	4·5	43·0	43·5

The comparison between columns 4 and 5 shows that in this case the Pitot tube indicates the arithmetical mean between the dynamic pressures due to the velocities v_1 and v_2.

Will this law also apply to cases in which the tube is allowed to remain for unequal lengths of time in the two columns, or, in other words, would the observed pressure coincide with the mean of the pressures due to v_1 and v_2, the latter being of course calculated by taking into account the length of time during which these velocities are acting?

This appeared probable, and the author attempted to verify it by arranging the pendulous movement so that the Pitot tube remained in the slow-moving current twice as long as in the more rapid one. The results obtained were analogous to those given, for example, in the following table :—

No. of Experiment. 1	h_1. 2	h_2. 3	h. 4	$\frac{h_1 + 2h_2}{3}$. 5
	mm	mm.	mm.	mm.
7	77·0	4·0	27·0	28·3
8	84·0	21·5	43·0	42·3
9	86·0	30·0	48·0	48·7
10	88·0	31·0	50·0	50·0
11	98 0	55·0	69·0	69·3

Except for No. 7 experiment, comparison supports the previous hypothesis. At the same time, it must be recognized that the regulation of the apparatus was more difficult in this case, and not so good as in the previous one, and that accordingly these figures have but a very relative value.

Keeping, however, to the results shown in the first table, it is clearly seen that the Pitot tube is capable of indicating very exaggerated velocities when applied to irregular currents. The following table shows the exaggeration of the velocities (column 7) in terms of the ratio between v_2 and v_1 (column 6); v (column 4) is the apparent velocity in metres per second indicated by the Pitot tube oscillating between two currents, when $\frac{v_1 + v_2}{2}$ (column 5) is the true mean velocity :—

No. of Experiment. 1	v_1. 2	v_2. 3	v. 4	$\frac{v_1 + v_2}{2}$. 5	$\frac{v_2}{v_1}$. 6	Exaggeration. 7	a. 8
	m.	m.	m.	m.		Per Cent.	
1	38·3	30·8	34·7	34·5	0·81	0·6	1·012
2	36·7	24·1	31·1	30·4	0·66	2·3	1·046
3	38·4	25·5	32·6	31·9	0·67	2·2	1·044
4	37·6	20 4	30·2	29·0	0·54	4·1	1·082
5	37·1	16·3	28·6	26·7	0·44	7·1	1·143
6	37·1	8·6	26·8	22·9	0·23	17·1	1·370

The last column (8) gives the value of the coefficient a which must be introduced into formula (2) : $h = a\frac{v^2}{2g}$, v being the true mean velocity (column 5).

It will be seen that this coefficient varies considerably. It remains less than the limits of the figure (1·15) generally adopted as long as the ratio of the velocities does not exceed 2, but it then rises very rapidly, tending towards the value 2. It might even become still higher if the period of action of the velocities v_1 and v_2 were unequal.

The curve given in Fig. 5 is a graphic expression of the preceding table. The ratios of $\frac{v_2}{v_1}$ form the abscissæ, and the relative excesses of velocity (e) shown by the Pitot tube are the ordinates.

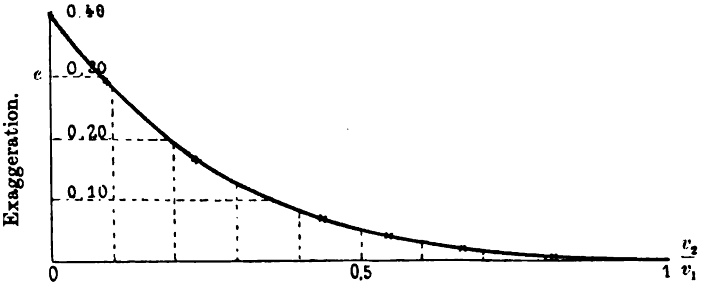

FIG. 5.

Thus, this instrument which is accurate in the case of a regular current, in the opposite case only measures the amount of velocity with a very rough degree of approximation. Nevertheless, the indication which it furnishes, if it is not referable to the mean velocity, always corresponds to something. What is it, then, that it measures? Our experiments show that when the periods of action of the velocities of v_1 and v_2 are equal, the tube indicates the mean of the squares of the velocities v_1 and v_2, and that there is every reason to suppose that this property extends to the general case in which the velocities vary in any manner whatever.

The Pitot tube is therefore an instrument which measures, not the mean velocity, but the mean of the squares of the velocities ; that is to say, the quantity of mean motion.

This question is closely connected with what has been called the Dubuat paradox. It is wellknown that Chevalier Dubuat discovered that the pressure exerted by a current of water of a mean velocity, v, upon a thin plate plunged into it normal to the direction of the fluid motion is considerably greater than when the water is at rest and the plate is moved in it with the same volocity, v. This is naturally explained by the fact that the water-current is irregular, and that its quantity of motion is therefore greater than if all the particles had the same velocity, v. This may be explained as follows:— Let s be the area of the thin plane. The pressure F is connected, according to the theorems of general mechanics, with the quantity of motion absorbed in the unit of time.

Let us first suppose that the velocity, v, of the fluid-films in relation to the plane is exactly the same for all, and does not vary with the time. This is what exactly happens when the plane is moved in the water, the latter being at rest. The mass of fluid affected by the plane in the unit of time over the section s has a mass equal to $\frac{\omega}{g} sv$, ω being the specific weight of the liquid, and its quantity of movement is accordingly $\frac{\omega}{g} sv^2$. Accordingly—

$$F = K\frac{\omega}{g} sv^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

It is necessary to introduce a coefficient, K, greater than unity, on account of the form of the wave of water produced by the thin plane, owing to which the mass of water affected by the plane has a section greater than s. This formula shows that the thrust, F, and the quantity of movement (momentum) are proportionate to the square of the velocity v.

If the plane is now supposed to be fixed and an irregular current whose mean velocity is v_m to impinge upon it, the amount of motion absorbed by the plane will be greater than $K\frac{\omega}{g} sv_m^2$ in the unit of time, because the mean of the squares is always greater than the square of the mean. The pressure which is here the mean of the expression $K\frac{\omega}{g} sv^2$ taken in reference to space and to time, will therefore be greater than in the preceding case, and will be greater in proportion as the current is more irregular. The ratio between the two pressures, less 1, is to some extent the indication of the degree of irregularity of the velocities. We may make this notion more precise by defining what we shall call the coefficient of irregularity.

Let us take $v = v_m + w$,

v_m being the mean velocity for a period of time, T, of considerable length; the value of w will be at times positive and at times negative, and according to the definition,

$$\int_0^T w dt = 0.$$

In considering a section of current, $d\sigma$ infinitely small, the quantity of motion which passes through it in the time dt is equal to—

$$mv = \frac{w}{g} d\sigma . v^2 dt.$$

For the period T, and for the mean quantity of motion, q of this flow,

$$q = \frac{w}{g} d\sigma . \frac{1}{T} \int_0^T v^2 dt.$$

Taking out the square $v^2 = v_m^2 + 2w . v_m + w^2$, and noting that v_m is constant and that $\int w dt = 0$, we get—

$$q = \frac{w}{g} v_m^2 (1 + \epsilon) d\sigma, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

when

$$\epsilon = \frac{\int_0^T w^2 dt}{v_m^2 T} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

This quantity, ϵ, always positive, and greater according as the values of w are greater—that is to say, the more irregular the current, is what we call the coefficient of irregularity of the current in relation to time.

It is evident that the mean quantity of motion of the current is equal to what it would be if the velocity were constant and multiplied by $(1 + \epsilon)$.

In the same way the coefficient of irregularity might be defined with reference to the extent of any part whatever of the total section of the current, and calling V_m the mean total velocity of the current during the time T,

$$\eta = \frac{\int (v_m - V_m)^2 d\sigma}{V_m^2 \sigma} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

The mean quantity of motion of the whole current would then be:—

$$Q = Q_0 (1 + \eta) (1 + \epsilon),$$

Q_0 being the quantity of motion which would exist if the velocity in each section were constantly equal to the mean velocity V_m, and ϵ were a mean of the various values referable to the different sections.

Analogous considerations apply to the *vis viva.*

"It thus appears, and it is a remarkable fact to which attention cannot be too carefully directed, that on account of the mere fact of the inequality of velocities in a current of fluid, the quantity of motion and the *vis viva* of this current are always greater than would be the case if every section of it had the same mean velocity."*

The Dubuat paradox has at times also been explained by referring the change to K and not to v^2, and by supposing that the wave is not the same when the plane is fixed as it is when it moves. Without absolutely denying that there may be some change of this nature, the author thinks that the chief explanation of the phenomenon depends upon the irregularity of the velocities. This allows us to understand why different observers have found very variable coefficients of pressure with equal mean velocities, and notably why the pressure of the wind is stronger when it blows in gusts than when it is regular.

Without carrying this argument further, it may be concluded that: the Pitot tube is an instrument for measuring the mean quantity of motion of fluid currents. From this the mean velocity can be derived, if the coefficient of irregularity of velocity with reference to time is known, a coefficient which is sometimes zero and sometimes may rise to 1, or even higher.

II.—ANEMOMETERS.

Hydrometers and anemometers on the wind-mill or fan principle are always graduated by moving them with known and increasing velocities in the fluid, air or water, the latter being at rest. Sometimes this motion is rectilinear, as for example when the Woltmann mill is graduated by dragging it through water by means of a rod supported by a boat, or by a waggon running on rails. More frequently rotation about a vertical axis is employed, but the radius of rotation is then made sufficiently long compared to the diameter of the fan, for the relative velocities of the fluid to vary but little as between different parts of the instrument. In either case, the action is the same as though the mill received the impulse of a perfectly homogeneous current having its elements of instantaneous velocity invariable both in time and space, or at all events varying between very narrow limits.

What then will happen when the instrument is employed to measure the velocity of an irregular current? Reasoning would indicate, and experiment has proved, that it will then be more sensible to high velocities than to feeble ones, and that the result will be a greater total number of revolutions of the mill than that which should correspond, according to calibration, to the mean velocity, or, in other words, the instrument will indicate an exaggerated speed.

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* Prof. Flamant, *Hydraulique*, page 46.

Messrs. Aguillon, Fumat and Murgue, who have in two special cases found this exaggeration to be equal to 0·10 and 0·17 respectively, give precisely the same explanation of it. In the wellknown report which they have published upon their experiments,* these engineers say :—

> When an anemometer is moved on a revolving arm, the relative motion of the air that strikes it is perfectly regular, all the molecules acting with an equal velocity and in the same direction. In the drift of a mine, on the contrary, the movement of the air is utterly irregular. This may be shown by an exceedingly simple experiment. A small piece of cloth attached to a revolving arm takes immediately its position of equilibrium, and moves parallel to itself without vibration. This same cloth, when affected by the air-current of a mine, will be violently agitated, and will move in all directions about its mean position. It hence follows that when an anemometer is placed facing the current in a section to be measured, the molecules that strike it are animated by very different velocities, and because the *vis viva* of these molecules is in proportion, not to their simple velocities, but to the squares of their velocities, high speeds have more effect than low ones, and in consequence the mean result is exaggerated.

By means of the following experiments the author will be able to put beyond doubt that it is the irregularity of the velocities that falsifies manometric measurements and invariably exaggerates them. But it is necessary to distinguish irregularity in time from irregularity in space. The first acts owing to the inertia of the mill, and the second without this inertia influencing the result. In both cases, moreover, it is the amount of motion of the current that has to be considered and not the *vis viva*.

Let us first examine the irregularity in time, the most important, undoubtedly, for measuring air-currents for mine-drifts, and afterwards we shall examine the irregularity in space, which is, on the other hand, the preponderating one when water-currents are being gauged, as in the latter case the inertia of the mill may be neglected.

Irregularity in Time.—The apparatus used was that which gave satisfactory results in the study of the Pitot tube. The writer produced two homogeneous air-currents, flowing side by side, by means of two rectangular boxes, having each a section of 100 by 125 millimetres and a length of 400 millimetres. These pipes issued from a box into which a fan was blowing air, the pressure being variable at will. The intake end of each tube was covered by wire gauze and by a piece of cloth pierced with very numerous holes arranged as regularly as possible, so as to distribute the air-current uniformly throughout the whole section. By changing the pieces of cloth the velocity in either tube and the ratio of the two could be varied.

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* *Loc. cit.*, page 506.

The Casartelli anemometer, which formed the subject of these experiments, was placed in front of the orifices of these tubes.

A permanent condition was maintained for a sufficient length of time, say about 5 minutes. The number of divisions traversed by the hand of the anemometer per minute was first counted, the instrument being maintained fixed successively in each of the currents. Then, by means of a heavy pendulum mounted on a knife-edge and swinging at the rate of about two-thirds of a second, the anemometer was made to oscillate for 2 minutes between one current and the other, and the number of divisions traversed was again read off. The apparatus was so arranged that the oscillations should be symmetrical with reference to the median division, so that one was certain that the anemometer remained an equal length of time in each of the currents. It thus received alternately during periods equal to about two-thirds of a second the impulses of a current of high velocity v, and of low velocity v_2. The period during which it remained in the intermediate zone, where it received at the same time a portion of each of these currents, was so short that it may be possible to admit, roughly speaking, that it passed practically direct from one to the other.

If the inertia of the instrument had been *nil*, the wheel would each time have assumed instantly a rapidity of rotation corresponding to that of the air-current which was traversing it, and the total of the divisions traversed during the 2 minutes should have been exactly equal to the sum of the number of divisions traversed in each portion separately during one minute, because the equation which connects the velocity v with the number of revolutions n is linear ($v = a + bn$). But, on account of this inertia, the wheel once started by the rapid current will continue to turn in the feeble current more rapidly than it ought to, whilst in the return stroke, on the contrary, it will rapidly assume a velocity corresponding to that of the stronger current. An exaggeration of velocity will therefore be shown by the mill and will be more strongly marked, the more rapid these alternations are. The theory will be explained presently: the results of the experiments will be given first. The following table indicates some of these. Columns 2 and 3 correspond to the divisions n_1 and n_2 traversed in each of the currents separately; column 4, those divisions n' which have been recorded with a pendulous movement from one current to the other; column 5, the ratio of the velocities $\frac{v_2}{v_1}$; and, finally, column 6, the exaggeration obtained with the pendulous movement.

No. of Experiment. 1	n_1. 2	n_2. 3	n'. 4	$\frac{v_2}{v_1}$. 5	Exaggeration. 6
					Per Cent.
1	855	0	1,048	0·000	22·5
2	718	0	905	0·000	26·2
3	482	0	643	0·000	33·5
4	340	0	450	0·000	32·4
5	870	210	1,157	0·250	7·1
6	643	157	883	0·256	10·4
7	437	121	634	0·292	13·6
8	417	94	596	0·243	16·6
9	190	39	278	0·243	21·3
10	614	333	957	0·550	1·1
11	460	233	700	0·520	1·0
12	255	138	397	0·560	1·0

These experiments are neither sufficiently numerous nor sufficiently exact to enable the law of the phenomenon to be established. They show, however, that the irregularity in time certainly causes an exaggeration in the indications of the instrument. This exaggeration, very small when the ratio of velocities is greater than 0·5, becomes very marked when it falls to 0·25, and rises above 30 per cent. when one of the velocities becomes zero.

A comparison of Nos. 5, 6, 7, 8 and 9 experiments shows that this exaggeration decreases in proportion as the velocities increase simultaneously. The reason is that the synchronizing action of these currents increases proportionately, wherefore the inertia of the mill becomes relatively of less importance.

If these experiments were repeated with a liquid, it seems beyond doubt that the exaggeration due to inertia would be exceedingly feeble, because the inertia of the mill could be practically neglected in comparison with the mass of liquid traversing it.

The results of the preceding table can be divided into three groups, and if the mean of each group is taken the following figures result :—

Mean of the ratio of the velocities $\frac{v_2}{v_1}$	0·00	0·26	0·55
Percentage of the corresponding exaggeration	28·70	13·80	1·00

Their graphic representation gives a curve shown in Fig. 6, in which the abscissæ are the ratios $\frac{v_2}{v_1}$ of the velocities, and the ordinates the corresponding exaggerations. The curve thus obtained, although badly determined, on account of the small number of points, shows a certain amount of analogy with that got by the Pitot tube. This analogy cannot, however, be complete, because, for the Pitot tube, the curve is independent of the absolute rate of velocity, while here it depends both on the absolute values and on their ratios.

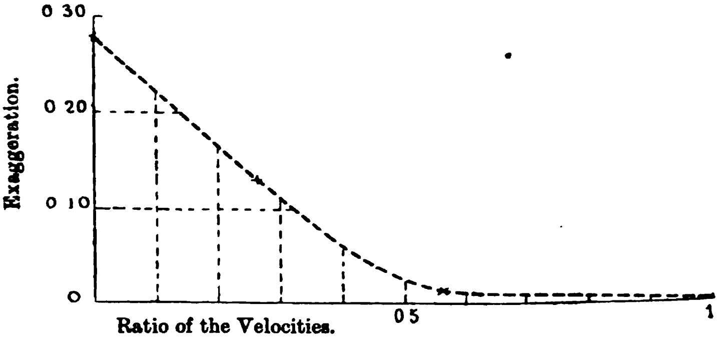

Fig. 6.

The period during which the anemometer remains in each current also plays an important part. The author has proved that this exaggeration diminishes in proportion as the duration increases. Here, for instance, are two experiments made by placing the apparatus alternately for 5 seconds in an air-current produced by a fan and in still air :—

Divisions registered in 1 minute in the current	987	410
Divisions traversed in 2 minutes with alternations ...	1,080	490
Exaggeration per cent.	9·5	19·4

or a mean of 14·5 per cent., while with alternations of about two-thirds of a second only, a mean exaggeration, say, of about 30 per cent. was recorded.

Theory.—The theory of this phenomenon is easily established on the basis of the formula which gives the moment of motion of a turbine. The moving wheel of the anemometer is in fact nothing else than a helicoidal turbine without a guide, moving always at about its maximum velocity, and the moving couple formed by the air or water that traverses it, may be expressed by means of the quantity of fluid passing per second, and by the deviation of the layers of the fluid caused by the movable vanes.

Let S be the section traversed by the vanes of the anemometer.

v, the velocity of the air or water through the anemometer.

Ω, the angular velocity of the anemometer at any instant.

$\Omega' = \frac{v}{\rho}$, the angular velocity when this mill is moving at the same rate as the current v.

Let ω be the specific weight of the fluid;

and g the acceleration due to gravity.

The mass of the fluid, I, that traverses the wheel in the unit of time is—

$$I = \frac{\omega}{g} Sv. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

The deviation produced by the walls is proportionate to the slip:— $\Omega' - \Omega$. If we call this mean deviation a, that is to say, the mean of the projections, upon the tangential velocity of the wheel, of the absolute velocities of the fluid after it has passed through this wheel, it may be taken that—

$$a = K(v - \rho\Omega) \sin \alpha \cos \alpha, \quad . \quad . \quad . \quad . \quad . \quad (11)$$

when α is the mean inclination of the vanes to the plane perpendicular to the axis of the mill, and K is a coefficient depending upon the number and size of the vanes.

In applying, now, the theorem of the moments of the quantities of motion, the moment producing motion of the anemometer would be—

$$M = \Sigma i a r = IaR, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

calling R the mean radius of the wheel.

Wherefore, if H designates the moment of inertia of the wheel with reference to its axis, the differential equation of its moment will be

$$H \frac{d\Omega}{dt} = M = IaR;$$

or, replacing I and a by their values (10) and (11)

$$H \frac{d\Omega}{dt} = \frac{\omega}{2g} SR \sin 2\alpha . K . v \, (v - \rho\Omega), \quad . \quad . \quad . \quad (13)$$

or again,

$$H \frac{d\Omega}{dt} = \lambda \omega v \, (v - \rho\Omega), \quad . \quad . \quad . \quad . \quad . \quad . \quad (13b)$$

λ being a constant of the construction of the apparatus.

This equation is linear, and of the first order, while Ω may be calculated if the expression of v in terms of time is known. Without solving it, it may be seen that the value $\frac{d\Omega}{dt}$ due to the angular velocity —that is to say, the rapidity with which the wheel assumes its proper speed—is proportionate to the specific gravity ω of the fluid, and inversely proportional to the moment of inertia of the mill.

Whence it follows that, in the construction of anemometers for the purpose of measuring air-currents, care must be taken to make the moving wheel as light as possible, while at the same time avoiding any possibility of its deformation under the action of the highest rates of velocity which the apparatus will be called upon to measure.

It will be seen that the second member of the equation includes v as a factor, which explains why, owing to their quantity of motion, high velocities are more rapidly synchronized than low ones.

Assuming that—

$$\frac{\lambda\omega}{H} = \mu, \quad \ldots\ldots\ldots \quad (14)$$

the differential equation may be more simply written—

$$\frac{d\Omega}{dt} + \mu\rho v\Omega = \mu v^2, \quad \ldots\ldots \quad (15)$$

the general solution of which is—

$$\Omega = \mu e^{-\mu\rho\int v dt}\int v^2 e^{\mu\rho\int v dt} dt. \quad \ldots\ldots \quad (16)$$

This integration will always be possible if v is known in terms of the time, but it will generally be exceedingly complicated. It becomes especially so in the case of our experiments, where v alternates abruptly from one velocity v_1 to another v_2, which are always the same, and each of which are acting during the same period of time τ. The angular velocity thus oscillates, when a permanent condition is established, between a maximum Ω_1 and a minimum Ω_2, both lying between $\frac{v_1}{\rho}$ and $\frac{v_2}{\rho}$. It is easy to calculate Ω_1, Ω_2, and the mean angular velocity Ω_m.

In the interval between a consecutive maximum and minimum, the velocity v of the current remains invariable; then the general integral of the equation with a constant C is—

$$\Omega = \frac{v}{\rho} + Ce^{-\mu\rho vt} \quad \ldots\ldots\ldots \quad (17)$$

Accordingly, starting from the minimum, we obtain—

$$\frac{v_1}{\rho} - \Omega = \left(\frac{v_1}{\rho} - \Omega_2\right)e^{-\mu\rho v_1 t};$$

and, starting from the maximum,—

$$\Omega - \frac{v_2}{\rho} = \left(\Omega_1 - \frac{v_2}{\rho}\right)e^{-\mu\rho v_2 t}.$$

If the value τ, the period of the alternations, is given to t, we obtain as follows, putting $m = \mu\rho\tau$, in order to simplify the equation:—

$$\frac{v_1}{\rho} - \Omega_2 = \left(\frac{v_1}{\rho} - \Omega_1\right) e^{mv_1};$$

$$\Omega_1 - \frac{v_2}{\rho} = \left(\Omega_2 - \frac{v_2}{\rho}\right) e^{mv_2}.$$

From the above values, Ω_1 and Ω_2 can be obtained—

$$\Omega_1 = \frac{v_1}{\rho} - \frac{v_1 - v_2}{\rho}\,\frac{e^{mv_2} - 1}{e^{m(v_1 + v_2)} - 1}, \quad . \; . \; . \; . \quad (18)$$

$$\Omega_2 = \frac{v_2}{\rho} + \frac{v_1 - v_2}{\rho}\,\frac{e^{mv_1} - 1}{e^{m(v_1 + v_2)} - 1}. \quad . \; . \; . \; . \; . \quad (19)$$

These formulæ show that Ω_1 and Ω_2 lie entirely between $\frac{v_1}{\rho}$ and $\frac{v_2}{\rho}$, and that, moreover, Ω_1 is nearer to $\frac{v_1}{\rho}$ than Ω_2 is to $\frac{v_2}{\rho}$, because $e^{mv_2} - 1$ is smaller than $e^{mv_1} - 1$.

The graphic representation of the angular velocity of the mill in the function of the time is of the following kind :—

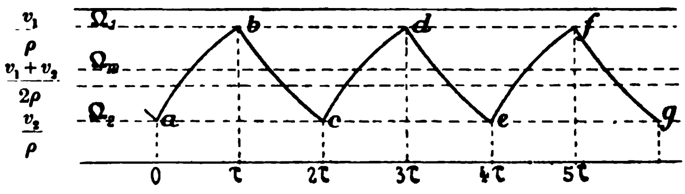

FIG. 7.

The curve *abcdefg* . . . . consists of logarithmic segments.

Calculation gives as the value of the mean angular velocity—

$$\Omega_m = \frac{v_1 + v_2}{2\rho} + \frac{(v_1 - v_2)^2}{2\rho v_1 v_2}\cdot\frac{(e^{mv_1} - 1)\,(e^{mv_2} - 1)}{m(e^{m(v_1 + v_2)} - 1)}. \quad . \; . \quad (20)$$

The first term of this expression is precisely that which corresponds to the mean velocity $\frac{v_1 + v_2}{2}$ of the current. The second is the exaggeration due to the inertia of the mill. The relative value of this exaggeration ϵ is therefore as follows :—

$$\epsilon = \frac{(v_1 - v_2)^2}{(v_1 + v_2)\,v_1 v_2} \times \frac{(e^{mv_1} - 1)\,(e^{mv_2} - 1)}{m\,(e^{m(v_1 + v_2)} - 1)} \quad . \; . \; . \quad (21)$$

ϵ will be very small if m is very great—that is, if the inertia of the mill can be neglected, or if the specific gravity of the fluid is very great, as in the case of liquids ; or, again, if the period of alternations is great. It increases in proportion as m diminishes, and tends towards a determinate limit when m tends towards zero, as in the case of very great inertia or very rapid alternations.

At this limit, which is

$$\epsilon = \left(\frac{v_1 - v_2}{v_1 + v_2}\right)^2, \quad . \; . \; . \; . \; . \; . \; . \quad (22)$$

Ω_1, Ω_2, and Ω_m become equal, and the velocity of the mill no longer varies sensibly.

The curve of e in functions of the ratio of the velocities $\frac{v_2}{v_1}$ has, in this case, almost absolutely the same shape as in the case of the Pitot tube (Fig. 5), but with ordinates which are greater in the proportion of 2·5 to 1, very nearly. It will, therefore, be understood that these two curves will almost coincide, if the quantity m has a suitable value, and this explains the agreement which is sometimes to be met with in the indications of these two measuring instruments. It will also be seen that this agreement can only take place under very special conditions.

From the formula (21), some further rather remarkable direct results may be deduced.

By taking $v_2 = 0$, ϵ becomes equal to 1. In these experiments, the exaggeration will certainly be constant and equal to 1, whatever be the values of v_1 and the period τ of the alternations; while the table of experimental results shows that the exaggeration has only reached, in reality, a mean of 30 per cent. The reason is, that our theory is no longer applicable at this limit.

When the apparatus is introduced into quiescent air, the mill does not continue to turn without slackening speed, but the wheel becomes a fan, and forces a certain volume of air to traverse the machine. This result is better marked the more rapid the velocity of rotation, wherefore the exaggeration ϵ, should be found to diminish in proportion as the velocity v_1, increases. Nos. 1, 2, 3, and 4 experiments are, upon the whole, in agreement with this conclusion.

This no longer obtains when v_2 has an appreciable value compared to v_1. Let $\frac{v_2}{v_1} = x$ and $mv_1 = y$, formula 21 may then be written as follows:—

$$\epsilon = \frac{(1-x)^2}{1+x} \frac{(e^y - 1)(e^{xy} - 1)}{xy(e^{y+xy} - 1)}. \quad . \quad . \quad . \quad . \quad (23)$$

It is easy to see that ϵ decreases when v_1, that is to say, when y increases. When y is sufficiently great, the value of unity may be neglected compared to the exponentials e^y, e^{xy}, and by suppressing it in the expression for ϵ, the simple result obtained is—

$$\epsilon = \frac{(1-x)^2}{(1+x)\,xy}.$$

Consequently, when the ratio x is constant, the exaggeration ϵ, if sufficiently small, is almost inversely proportional to the velocities v_1 and v_2. This approximate law is very fairly verified by Nos. 5, 6 and 8 experiments, which fulfil the conditions.

This discussion, upon the simplest special case that can occur, shows how complex is the phenomenon of the irregularity of the velocities in time. It obeys complicated laws, the expression of which cannot possibly be given in a simple statement.

Irregularity in Space.—It must always be borne in mind that the mill is not struck at the same moment by fluid layers, all of which have the same velocity. The non-homogeneity of the current has also the effect of accelerating the velocity of the mill, and this cause of inaccuracy remains unaffected even when the other becomes zero.

As in the preceding case, the moment of motion will be stated by the aid of formula 12. Let us suppose that the wheel encounters layers of fluid, each of which has individual fixed velocities. It will then take the angular velocity Ω, such that the moment of motion M will be zero. We should therefore have $\Sigma iar = 0$.

Let $d\sigma$ be the cross-section of a current of velocity v. For this portion of the current $i = \frac{w}{g} v d\sigma$, and $a = \frac{K}{2} \sin 2\alpha (v - \rho\Omega)$; by substitution, we obtain—

$$\frac{Kw}{2g} \Sigma v (v - \rho\Omega) \sin 2\alpha . r d\sigma = 0;$$

hence,

$$\rho\Omega = \frac{\Sigma v^2 \sin 2\alpha . r d\sigma}{\Sigma v \sin 2\alpha . r d\sigma}.$$

The angle α is generally constant for the entire length of the vane. This at least is the case in the Biram, Casartelli and Casella anemometers, which are the most used at present.* The factor assigned to $\sin 2\alpha$ may, however, be suppressed both in the numerator and in the denominator. It is also possible to suppress r (the radius of the section of fluid) if the vane is sufficiently short. We should then have—

$$\rho\Omega = \frac{\Sigma v^2 d\sigma}{v_m \sigma} = v_m (1 + \eta). \quad . \quad . \quad . \quad . \quad . \quad (24)$$

v_m being the mean velocity, and η the coefficient of irregularity as defined in equation 9. This approximate formula shows that when the current is not homogeneous, these anemometers give, not the mean velocity, but the mean quantity of motion, and are thus analogous to the Pitot tube.

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* The old Woltmann mill, like the forms here mentioned, consists of flat vanes, relatively short, united to the boss by means of light arms. Fans are also constructed, especially for hydrometers, which, like the Baumgarten mill, have vanes that start directly from the boss: these vanes then receive a helicoidal form. The formula (24) may also be applied to this form of fan, but only as an approximation.

The exaggeration of the apparent measure of the mean velocity which will then result, may become very perceptible. It will generally be less, in the case of anemometers employed in air-currents, than that which is occasioned by irregularities in time. The Woltmann mills for measuring water-currents, although inaccurate, are very much less so than those used for measuring air-currents.

The author has ascertained experimentally that irregularity in space produces an exaggeration in the velocity of the mill. It was sufficient for this purpose to place the instrument between the two currents mentioned above in such a manner that each should act upon one-half of the moving wheel. The results, although very clear as regards the nature of the divergency. did not seem to be sufficiently regular to be given here. In the neighbourhood of the zone of contact between the two currents, it is probable that these velocities mutually modified one another, so that one cannot be quite sure that the instrument is only exposed to the two velocities v_1 and v_2. The experimental method does not therefore submit the formula (24) to an exact verification; it only serves as a demonstration of the increase of the velocity of the mill but not of the value of this increase.

III.—EQUATIONS FOR ANEMOMETERS AND HYDROMETERS.

We have supposed in the preceding sections that the equations for anemometric mills—that is to say, the ratio which connects the velocity v of the current with the number of divisions n traversed by the index in the unit of time—is linear, and that it may be expressed by: $v = a + bn$. It is certain that the calibration of hydrometers and anemometers agrees well with this formula when v exceeds 0·5 metre per second. If the usefulness of a term varying as n^2 has been recognized for higher velocities, it has been generally in the case where the vanes of the mill bend under the impulse of the fluid.* This formula is, however, no longer accurate for velocities less than 0·5 metre per second. The error which it may cause is not very considerable, as it does not exceed 4 or 5 per cent. Nevertheless, in measurements of great accuracy it is important to cause it to vanish as nearly as possible.

Experiment and theory agree in indicating the presence in the formula for the mill of a term in values of $\frac{1}{v}$, which would only be noticeable at low velocities. Let us first see what theoretical considerations would indicate.

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* This subject will be referred to later on. The curve of calibration would seem in reality to be somewhat sinuous.

Numerous theories of anemometers have already been given: that of Mr. Chasles * leads to the formula $v = a + bn$; as also does that of Mr. Charles Combes, † who wishes, moreover, to make the coefficient inversely proportional to the square root of the specific weight of the fluid which is being experimented upon. Finally, Mr. Baumgarten ‡, by an analysis similar to our own, has obtained the following formula:—

$$v = an + \sqrt{bn^2 + c}, \quad . \quad . \quad . \quad . \quad . \quad . \quad (25)$$

a, b and c being three constants.

These formulæ will be discussed later on, and compared with that here given, which will be established as follows:—

The couple producing movement, per formulæ 12 and 13—

$$M = IaR = \frac{K\omega RS \sin 2\alpha}{2g} v^2 \left(1 - \frac{\rho\Omega}{v}\right), \quad . \quad . \quad . \quad (13)$$

due to the ratio of slip $\left(1 - \frac{\rho\Omega}{v}\right)$, which produces a thrust of the fluid upon the vanes, must balance the resisting couples derived from:

1. The impulse of the fluid upon the arms of the mill (when it has any) and upon the entering edge of the vanes, and of the friction of the fluid upon these vanes. This couple has the following form:—

$$f(v) = \frac{\omega}{g}(dv + ev^2), \quad . \quad . \quad . \quad . \quad . \quad . \quad (26)$$

d and e being two constants, of which the first is generally minute and only noticeable for very low values of v.§

2. From the friction at the pivot produced by the longitudinal thrust of the fluid upon the vanes and upon the arms; the resisting couple resulting from this may be very feeble, and in every case almost exactly proportional to the preceding one. We shall therefore include it in the same expression.

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* *Cours de l'Ecole Polytechnique*, 1844. † *Annales des Mines*, 1838.

‡ "Sur le Moulinet de Woltmann, destiné à mesurer les Vitesses de l'Eau, sur son Perfectionnement et sur les Expériencès faites avec cet Instrument (On the Woltmann mill, designed to measure the Velocities of Water, on its Improvement and Experiments made by this Instrument)," by Mr. Baumgarten, *Annales des Ponts et Chaussées*, 1847, second half-year.

§ This thrust of the fluid upon the vanes and upon the arms is due to its relative velocity, which is always at the same point of the mill sensibly proportional to the absolute velocity v, for the slip remains small even at low velocities. On the other hand, this thrust is exercised in the direction of the relative velocity, and differs but little from the tangent to the vane. In order to get its moment referred to the axis of the mill, it must be projected upon a plane perpendicular to this axis, and the angle of projection remains at every point sensibly the same for all velocities. It may, therefore, be said that the resisting moment due to the thrust of the fluid upon the entering edge of the vanes and upon the arms, which is strictly a function of n and of v, may be reduced, neglecting very small terms, to the simple function of v, and may be written in the form $f(v) = dv + ev^2$; and it is known that the first term dv exercises a distinct effect only with very feeble velocities.

3. From the friction of the axes and wheels of the gearing, due to the weight of these parts; this couple may be considered as constant; we will designate it by f.

4. And lastly, if the apparatus is graduated by means of a revolving arm, the centrifugal force $\frac{mv^2}{R}$ (R being the radius of the circle described by the centre of the instrument) will produce an additional pressure of the axes against their bearings, and consequently an additional friction to which a couple of the form $f' \frac{v^2}{R}$ corresponds.

Equating the couple producing motion to the sum of the couples resisting it, the following expression is obtained :—

$$\frac{K\omega RS \sin 2a}{2g} v(v - \rho\Omega) = \frac{\omega}{g}(dv + ev^2) + f + f' \frac{v^2}{R}; \quad . \quad (27)$$

or dividing the two members by v, and replacing Ω by the number n proportional to it—

$$\left(\frac{K\omega RS \sin 2a}{2g} - \frac{\omega}{g} e - \frac{f'}{R}\right) v = An + \frac{\omega}{g} d + \frac{f}{v}, \quad . \quad . \quad (28)$$

an expression which has the form—

$$v = a + bn + \frac{c}{v}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (29)$$

a, b and c being three constants, the expressions for which it is not necessary to obtain and which show that—

1. The constant a, always very small, varies a little with the radius of the arm of the testing-machine, and also, no doubt, with the specific weight ω of the fluid and the shape of the vanes of the mill.

2. The constant b is slightly increased when the radius R of the arm of the testing-machine is diminished.

3. The constant c is very small and, neglecting the influence of the radius of the arm of the testing-machine, inversely proportional to the specific weight ω of the fluid, and not to the square root of the specific weight, as was found by Mr. Combes. This constant c, which we shall prove is sensible in the case of air, will no longer be so, the friction remaining the same, when the apparatus is used in water, in which latter case the equation should be perfectly linear, or $v = a + bn$. But hydrometers must be constructed more substantially than anemometers, and the absolute value of the friction is very much greater, wherefore the term $\frac{c}{v}$ exists in the equation for hydrometers, as will be shown later on.

These conclusions appear to be generally verified by experiments both on hydrometers and anemometers. The latter will be taken first.

1. *Anemometers.*—The influence of the radius of the testing-machine upon the value of the constant b is difficult of proof. The author has made a considerable number of experiments on this point,* by placing the anemometer at radii of 2 and 1½ metres, and 1 and ½ metre, and he has found a very considerable effect due to the length of the radius, but it sometimes corresponded in direction to the effect of centrifugal force and sometimes acted in the opposite direction. In the latter case, the result would probably be interfered with by the bending of the support which formed the spindle of the revolving-arm under the action of centrifugal force developed by the revolving-arm. This bending certainly produced an increase of the radius of rotation, in proportion as the angular velocity increased. It is, therefore, not possible to say that the influence of R upon the value of the constant b has been definitely fixed by these experiments, on which account it is unnecessary to give here the detailed results. In order to obtain a definite determination, a less rudimentary installation than that used by the author would have to be employed. †

On the other hand, the author's experiments, as well as the tests published by Mr. D. Murgue, indicate clearly the existence of the term $\frac{c}{v}$. In order to show it distinctly in curves, the preponderating influence of the term bn must be got rid of by taking as ordinates not v, but $v - \beta n$, β being a constant *à priori* taken somewhere near to b. The equation will then be :—

$$y = v - \beta n = a + b'n + \frac{c}{v}, \quad \ldots\ldots \quad (30)$$

in which three terms a, $b'n$, and $\frac{c}{v}$ have now analogous dimensions.

By replacing n also by its value in terms of v, we obtain :—

$$y = a' + b''v + \frac{c'}{v}, \quad \ldots\ldots\ldots \quad (31)$$

---

* The thanks of the author are due to his friend Mr. de Dianous, mining engineer, who has kindly given his assistance throughout all these experiments, which are tedious and troublesome, as is wellknown to all who have made any number of calibrations by means of the revolving arm.

† The author would like to remark that a careful installation made once for all, for instance in one of the Schools of Mines, of such a revolving testing-machine, would certainly be of great service, not only for scientific researches such as those undertaken by the author, but also for calibrating the anemometers which are regularly used in mines. Having regard to the need for accuracy which exists to-day, these calibrations have become indispensable, and engineers would certainly not fail to avail themselves of means which might be afforded them for calibrating their instrumeuts. At all events, there would always be one source of error the less. The author has heard this idea put forward by Mr. D. Murgue, manager of the Montrambert mines, who is a well-known authority on this question.

a' and c' being constants differing but little from a and c. The curve of y as ordinates in terms of v (abscissæ) should therefore, according to theory, be a hyperbola, the centre of which should be found in the axis of y at a distance a' from the origin, and the asymptotes of which

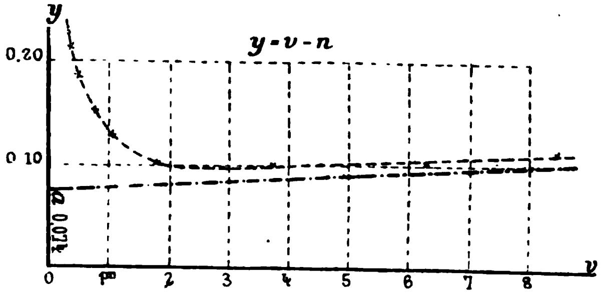

FIG. 8.

are (1) the axis of y, and (2) a straight line having b'' for its angular coefficient.

Figures 8 and 9 show, for example, two cases in which it is evident that the experimental points, indicated by crosses, follow hyperbolic curves.

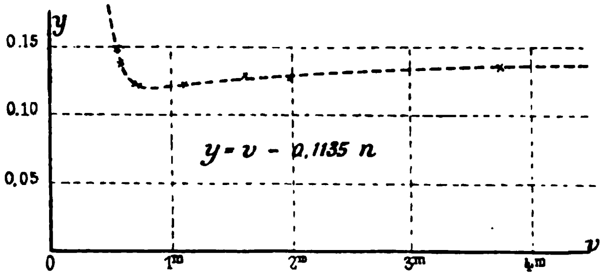

FIG. 9.

Fig. 8 shows the curve obtained by that one of the series of experiments in which the author used the lowest velocity ($v = 0{\cdot}31$ metre). Fig. 9 is the curve produced from the calibration of a Combes anemometer, published by Messrs. Aguillon, Fumat and Murgue in their report.*

The first calibration of an anemometer which was published, that recorded by Mr. C. Combes in his memoir of 1838, presents very clearly the same character.

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* *Loc. cit.*, page 594. This calibration and one given by Mr. Combes, which is about to be mentioned, are, so far as the author knows, the only calibrations among all those that have been published which show velocities sufficiently slow to allow of verification of the theory.

It may also be remarked that, according to the form of equation (29), the apparatus should only commence to turn when the velocity is notably greater than the value of the coefficient a; for when $n = 0$, we have:—

$$v_0 = \frac{a}{2} + \sqrt{\frac{a^2}{4} + c}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (32)$$

which is greater than a.

The author has shown by direct experiment that an anemometer for which the constant a was equal to about 0·08 did not commence to move until the velocity of rotation of the arm was greater than 0·25 metre per second;* while according to the linear equation with two terms $v = a + bn$, which would give $a = 0{\cdot}14$ metre, the apparatus ought already to commence to move at the latter velocity. It might be thought that, if the apparatus does not start for velocities between 0·14 and 0·25 metre, it is because the starting friction is greater than the running friction. But this explanation will not hold good, because it is easy to start the movable wheel by blowing upon it. But even after it has once been set in motion, it stops if the velocity of the revolving-arm does not exceed 0·25 metre per second.

It is self-evident that for these experiments to be successful they must necessarily be conducted away from the influence of air-currents, even the feeblest, and care must be taken to ensure that the rate of rotation shall be perfectly uniform; without which the slightest irregularity would suffice for the wheel of the anemometer to start, at all events from time to time.

It is evident that experiment agrees with theory to show that a term in the form of $\frac{1}{v}$ should be introduced into the formula for anemometers, and accordingly that the expression—

$$v = a + bn + \frac{c}{v}, \quad . \quad . \quad . \quad . \quad . \quad . \quad (29)$$

ought to be adopted.

It must further be added that this complementary term is only of influence at very slow velocities, inferior to 1 metre or even ½ metre per second, and even then the error committed in not employing it does not generally exceed 5 per cent., which may appear unimportant for the greater number of practical cases.

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* From $v_0 = 0{\cdot}25$ metre and $a = 0{\cdot}08$ metre, the value of c is obtained as 0·038 for the apparatus experimented upon, which agrees well with the value deduced from the curve of calibration.

2. *Hydrometers.*—The presence of the term $\frac{c}{v}$, due to the internal friction of the apparatus, is still more evident in hydrometers, as is shown by the calibration-experiments which are to be cited, after having compared the formula here given with those generally adopted.

By taking the number of revolutions n as abscissæ and the velocities v as ordinates, the formula $v = a + bn + \frac{c}{v}$ gives the hyperbola AB (Fig. 10), the centre of which is a point, C, situated upon the axis of the line of n, at a distance equal to a from the origin, and the asymptotes of which are: the one a straight line, with the angular coefficient b, and the other the line n. The working portion of the curve differs very slightly from the straight line, except in the immediate neighbourhood of the axis of the line v (for very low values of n) where it is further away from its asymptote.

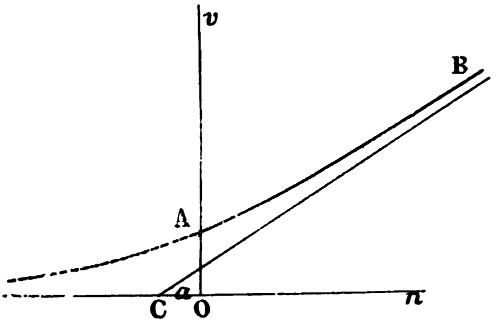

FIG. 10.

By suppressing the term $\frac{c}{v}$, the ordinary formula will be obtained, represented, as cartesian co-ordinates, by a straight line which does not pass through the origin.

The formula of Mr. Baumgarten, already mentioned,*

$$v = an + \sqrt{bn^2 + c}, \quad \ldots\ldots \quad (25)$$

presents a great analogy with our own. Expressed in the form of a curve, it is represented by a hyperbola AB (Fig. 11). Between these two curves there is the difference that the centre of the hyperbola is here situated at the point of origin of the co-ordinates, while this only happens with the author's curve when the constant a is zero. According to experiments by Prof. M. Schmidt,* which will be examined presently, this condition sometimes occurs, but not always.

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* *Ante*, page 146.

The rise of the curve of calibration of hydrometers at low velocities has long been known. Mr. Baumgarten† thought that he had observed it, and his formula explains it and takes note of it. His results, attacked by Mr. Laterrade,‡ who showed that the linear formula can be just as well applied to them, have been thoroughly corroborated by several series of experiments at Châlons under the direction of Mr. L'Eveillé, who has also discussed in a paper appearing in 1860 § the calibrations which had been made and published up to that date.

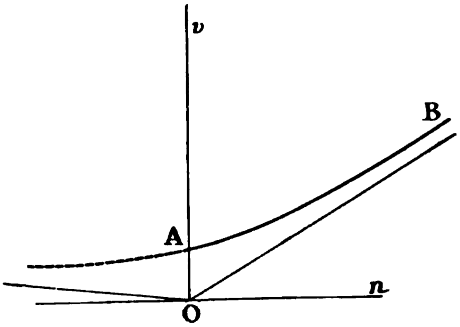

FIG. 11.

More recent experiments performed abroad, generally with great care, and by means of very perfect apparatus, all indicate a rise of the curve at low velocities, but the formula of Mr. Baumgarten cannot always be applied to them perfectly, while that here given, although it requires only three coefficients, seems to be thoroughly applicable to all cases.

As has been explained under the head of anemometers, if it is desired to show by means of curves the influence of the coefficients a and c, a method of plotting must be adopted which exaggerates greatly to the eye the changes produced by these coefficients. The author has already indicated one of these modes of plotting, which consists of making the values of v the abscissæ and $v - \beta n$ the ordinates. Prof. Schmidt has employed a still better method for studying low velocities.

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* *Zeitschrift des Vereines Deutscher Ingenieure*, 1895, vol. xxxix., pages 917 and 945.

† *Annales des Ponts et Chaussées*, 1847, second half-year.

‡ *Annales des Ponts et Chaussées*, 1858, first half-year.

§ "Note sur le Tarage du Moulinet de Woltmann et sur son Emploi dans la Mesure du Débit des Rivières (On the Calibration of the Woltmann Mill and on its Employment when Measuring the Volume of Rivers)," by Mr. L'Eveillé, *Annales des Ponts et Chaussées*, 1860, first half-year.

Let it be supposed that the instrument is made to traverse, with velocities v, variable in each experiment, but naturally constant throughout the whole of every one experiment, the same length L, which for the sake of simplicity may be taken as 1. Prof. Schmidt's curve is obtained by taking for the abscissæ the times x employed in traversing this distance, and for the ordinates the number of revolutions y of the hydrometer during this time. If the velocity of rotation of the hydrometer were strictly proportional to the linear velocity with which the instrument were moving, the number of revolutions y performed on a constant base L would always be the same, whatever the time x. This, however, is not the case. The curve of b in terms of x is obtained by replacing in the equation for the hydrometer, v by $\frac{1}{x}$ and n by $\frac{y}{x}$. It is then readily seen that :—

1. A straight line inclined towards the axes in terms of xy corresponds to the linear equation $v = a + bn$.

2. An ellipse or hyperbola, the axis of which is located according to the position of the axis of the line y would correspond to the formula of Mr. Baumgarten, and in a number of cases it may be a parabola, the apex of which lies upon the axis of y.

3. To the author's equation here given, a parabola always corresponds, the axis of which is parallel to the axis of the values of y, the apex being distant from this axis by an amount equal to $\frac{a}{c}$, because this formula when transformed gives :—

$$by = 1 - ax - cx^2. \quad . \quad . \quad . \quad . \quad . \quad . \quad (33)$$

The apex of this parabola will, however, only be upon the axis y when a is zero.

The experiments of Prof. Schmidt* were made with 12 different hydrometers, constructed by Messrs. Ertel & Sons, of Munich, Mr. A. Ott, of Kempten, and Mr. Amsler-Laffon, of Schaffhausen. The results are very clear. In the system of representing the results upon the lines xy, the experimental points always formed a curve. This curve is sometimes a parabola which has its apex in the axis of y (Nos. 4, 5 and 6 instruments), but not invariably so. Prof. Schmidt then applies either an ellipse (Nos. 1, 2 and 3 instruments) or an hyperbola (Nos. 7, 8, 9, 10, 11 and 12 instruments), so as to make use of the formula of Mr. Baumgarten. The agreement of these curves is generally good, but it is sometimes manifestly forced.

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* *Loc. cit.*

The author, on the contrary, has attempted to adapt all these cases to a parabola which may have its apex outside the axis of y. On the one hand, when the curve of Prof. Schmidt was an ellipse, and on the other hand, when it was an hyperbola, it would seem that a more satisfactory coincidence with the curve obtained experimentally was then produced.

Fig. 12 shows, for example, the diagram of the No. 12 anemometer to which Prof. Schmidt applied an hyperbola. It will be seen that the parabola AB, the apex of which lies somewhat to the left of the axis of y, agrees as well as possible, and better than the hyperbola, with the results obtained experimentally. The other examples lead to an identical conclusion.

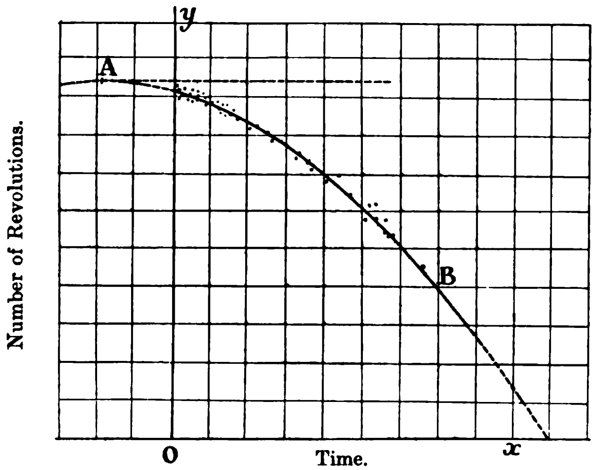

FIG. 12.

The author thinks that the formula which he has theoretically obtained has been verified by experiments, as far as regards correlating the velocity of motion v with the velocity of rotation n of the hydrometer, when the velocity is low. The coefficient a is zero in some cases, more generally positive, but it seems at times to be negative, but in so indistinct a manner that it cannot be affirmed with certainty that it really is negative.

The initial velocity with which the hydrometer commences to move was, in Prof. Schmidt's experiments, between 3·8 and 11·7 centimetres per second, giving a mean of 7·3 centimetres. Prof. Amsler-Laffon, instrument-maker, of Schaffhausen, now makes hydrometers with electrical transmission, which operates when the velocity is greater than 3 to 3·5 centimetres per second;* that is to say, as the internal friction is exceedingly slight, the term $\frac{c}{v}$ of the formula adapted to them is therefore exceedingly small, and becomes negligible so soon as the velocity exceeds 0·5 metre per second.

It may be asked, however, whether the formula $v = a + bn + \frac{c}{v}$, which holds good at low velocities less than 1·5 metres per second, is also true for greater velocities. The author is indebted to the kindness of Prof. Amsler-Laffon for precise information on this point, the result of which shows that the curve of calibration, which according to old observations was thought to be quite rectilinear above a velocity of 0·5 metre, really presents a sinuosity or hump which does not agree with the formula when the velocity exceeds 1·5 metres. This form of curve was noticed for the first time by Mr. Epper, engineer of the hydrographical department of Berne, who has made several very careful calibrations by means of special apparatus similar to that of Munich and Vienna. Fig. 13, for example, gives the curve obtained in a calibration communicated to the author by Mr. Epper, which is the result of more than 200 concordant observations. The velocities v with which the mill was moving have been taken for the abscissæ, and for the ordinates, as suggested for anemometers, the differences $v - 0{\cdot}24n$, n being the number of revolutions of the mill per second. This

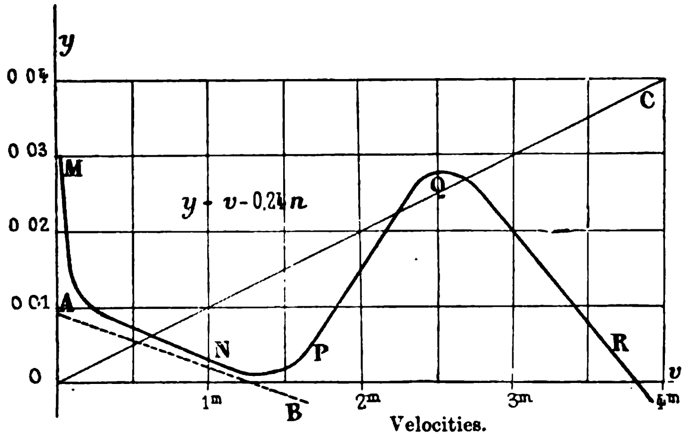

FIG. 13.

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* Every 50 revolutions, an electrical contact is made, which rings a small bell so as to give notice to the observer. This method of electrical transmission was suggested in 1859, and employed later on by Mr. Charles Ritter, *loc. cit.*

difference always remains small, less than 0·08, by which means small irregularities can be brought out by considerably increasing the scale of the ordinates.

If the results of calibration agree with the equation which has been given, the above curve would be an hyperbola, as already pointed out. It will be seen, in fact, that the portion of the curve MN, which gives velocities less than 1 metre, is really hyperbolic; but, above 1 metre, the curve leaves the hyperbola to rise and form a hump, the apex of which is situated at a velocity v, somewhere about 2 metres per second.*

On this curve, the hump appears enormous on account of the great magnification of the ordinates, which are fifty times the scale of the abscissæ. In reality, this sinuosity, although very well marked, does not remove the curve by more than 1 per cent. from the position which it would attain by employing the hyperbolic formula; † this would give

$a = 0{\cdot}0085$ metre, $b = 0{\cdot}24$ metre, and $c = 0{\cdot}0008$ metre.

The second series of calibration-experiments, covering about 140 determinations, performed by Mr. Epper, on another instrument of Prof. Amsler, has given the curve shown in Fig. 14, which is also analogous to the preceding one. The hump is also marked in it, and the same result has been obtained by several other calibrations.

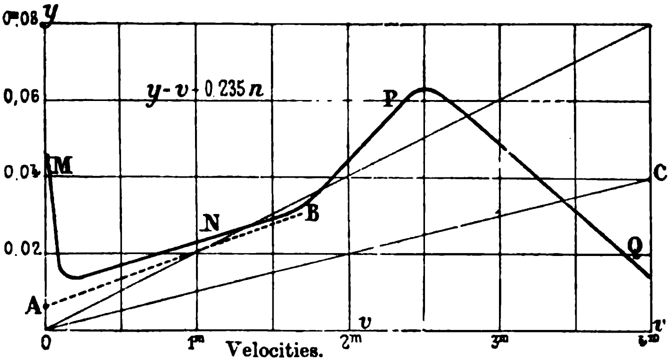

Fig. 14.

May it not be that this result, which has not been shown by the Munich experiments, is due to some peculiarity in Mr. Epper's mode of operating ?* It has not been found by Mr. K. Schmidt, Inspector of Hydraulic Construction at Danzig, who calibrated an instrument by Mr. Ott in the port of Dirschau up to velocities of 3 to 4 metres.

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* The asymptotes of the hyperbola being the straight lines Ay and AB, the parameters a and c will have the following very low values :—

$a = 0{\cdot}0085$ metre, and $c = 0{\cdot}0008$ metre.

† In the figure, the inclined straight line OC, makes the angle COv', which corresponds to a variation of ordinates of 1 per cent. of v.

The author is inclined to think, however, that its existence is quite certain, because this same sinuosity in the curve of calibration is to be found in the experiments made on calibrating anemometers on the revolving-arm (see Fig. 9) ; only in this case it takes place at a velocity which is generally different. What is the cause of this hump or sinuosity ?

Prof. Amsler-Laffon attributes the hump to the wave of displacement which is produced partly by the motion of the instrument itself, but generally by the cage in which it is mounted, and by the pole to which it is attached. It is, indeed, wellknown that every body moving in a fluid creates in it waves which follow every movement of the body. These waves are not the same at all velocities and there are critical velocities where the shape of these waves changes abruptly, as has been definitely proved with vessels moving at high speeds. These waves are also greatly modified by the width, and more particularly by the depth of the canal in which the body is moving.† If the preceding explanation is correct, the amount of sinuosity should diminish when a rod of small section is used, also when the experiments are performed in a canal of larger section, and when the instrument is immersed as deep as possible in the water.

Another cause may also be active, which seems to be even more real than the previous one. It has been seen that, according to the theory here given, the constants a and b of the formula depend upon the resistance due to the fluid acting against the edge of the vanes which cut through it, and upon the arms of the instrument, when it has any. This resistance has been expressed by the binomial expression $dv + ev^2$, and it was the coefficient d that gave the coefficient a of the final equation. It is quite certain that, at low velocities, the resistance of fluids is not proportional to the square of the velocity, but more nearly to the simple velocity. It was therefore necessary to take note of the coefficient d, as has been here done.

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* See also an article (pointed out to the author by Prof. Amsler) by Mr. K. Schmidt, Inspector of Hydraulic Constructions, in the *Centralblatt der Bauverwaltung*, October 27th, 1897.

† The canal in which the experiments of Mr. Epper were performed is 1·20 metres wide, 1·08 metres deep, and 120 metres long. The solitary waves which formed in it were propagated with a velocity which, according to the formula of Mr. Scott Russell, $v = \sqrt{gH}$, would be equal to 3·25 metres per second, and it may be noted that this velocity is but slightly greater than that which produces the hump in the curve.

For higher velocities, the resistance of the fluid becomes almost proportional to the square of the velocity, but not quite; and it would have been more accurate to have left this resistance in the general form $f(v)$. The following equation connecting n and v would then be obtained—

$$bn = v - \frac{c}{v} - \frac{f(v)}{v} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (34)$$

c being always dependent upon the internal friction of the apparatus, and $f(v)$ upon the resistance of the fluid. At low velocities, $f(v)$ approximates to the expression av, and thus the constant a is also introduced.

If, for all velocities, $f(v)$ could be put in the form of ev^2, $\frac{f(v)}{v}$ would be connected to the first term v of the second member, so as to give an equation without a constant. But, if $f(v)$ has a more complicated form than $av + ev^2$, which is certainly the truth, the curve represented by the preceding equation will not be one of the second degree.

In particular, the hump shown by the calibrations of Mr. Epper might be explained by introducing into $f(v)$ a negative term including v^3. It might be remembered on this point that the very careful experiments of Mr. de Mas on the resistance to the movement of vessels in canals have shown that the expression $\frac{f(v)}{v^2}$ presents a minimum for a velocity which lies between 1 metre and 1·5 metres per second, and this is precisely what also occurs in the calibration-curves drawn in Figs. 13 and 14.*

Without going farther, the author thinks that he has shown that all the peculiarities of the calibration-curves can be included in the general formula (34).

It would be easy to prove experimentally the preceding explanation, because, if it be correct, the sinuosity of the curves must diminish in proportion as the influence of the fluid upon the entering edge of the vanes is diminished. Therefore, to settle the point, it would be sufficient to compare an instrument with thick vanes and one with thin vanes, having their edges shaved down to nothing.

The preceding hypothesis supposes that the vanes do not lose their shape or bend under the action of the current. Cases have been distinctly proved where this bending produced an effect. The curve of calibration thus presents at high velocities a constantly increasing deviation from the straight line, but the bending of the vanes does not seem to explain the hump in the curve, and this cause must, therefore, in the writer's opinion, be set aside.

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* *Recherches expérimentales sur le Matériel de la Batellerie* (Experimental Researches on Shipbuilding Materials), by Mr. F. B. de Mas, Paris, 1891-1894.

It remains to decide experimentally what part is due to each of the two others given above. If it can be proved that the first has an influence which may be neglected when compared with the second, the mill would then give a simple means of studying the resistance of fluids in terms of their velocity.

Conditions which good Anemometers should Satisfy.—The preceding theory, thus supported by experiments, points out what are the conditions that anemometers should satisfy in order that the constants a and c should be as small as possible, and in order that the apparatus should be as little sensible as possible to the influence of the irregularity of the velocities of the air-current.

If it is desired to diminish the constant a, it is necessary to make the cutting-edges of the vanes of the mill as they enter the air very sharp, so as to diminish the impact against the air, and to arrange the arms in the same way, giving both arms and vanes a helicoidal form. As regards the constant c, it depends entirely on the friction of the pivots and the teeth of the wheels which communicate the movement of the mill to the index, and it accordingly depends upon the care with which the apparatus is constructed.

As regards the influence of irregularity in time, it has already been indicated that to diminish it it is necessary to make the moving portions as light as possible; but there is also another favourable condition with which compliance is easy. The formula (13) shows that the quantity $\frac{1}{\omega}\frac{d\Omega}{dt}$, that is to say, the relative rapidity with which the wheel attains its normal speed, depends mainly on the $\sin 2\alpha$. It will therefore be a maximum when $\sin 2\alpha = 1$, which leads us to incline the vanes of the mill in the most active portion of the machine, that is to say, nearest to the circumference, at an angle of 45 degrees to the plane perpendicular to the axis. This rule is, moreover, approximately observed in the majority of anemometers.

Errors Inherent to the Method of Calibrating by means of a Revolving Arm.—It may be remarked that in this method of calibration certain causes of error are to be feared.

First of all, the anemometer comes in contact with the fluid with variable velocities proportional to the radii of rotation of the points of impact. To be quite exact, the exaggeration of velocity caused by this irregularity must, as we have seen, be taken into account. The equation (24) shows that this exaggeration may in practice be entirely neglected. This equation would lead us to take for the velocity of the anemometer, not that which corresponds to the radius of the circumference described by its centre, but this radius increased by a quantity approximately equal to $\frac{\lambda^2}{8}$, λ being the ratio between the radius of the anemometer and the radius of the revolving arm. For instance. for a Casartelli anemometer revolving on an arm of 1 metre in length, λ is about equal to $\frac{1}{30}$, and $\frac{\lambda^2}{8} = \frac{1}{7{,}200}$, which is far from being a sensible amount.

This would not be the case, if the ratio λ attained to greater values, and an experimental proof is furnished in the tests made by Mr. Baumgarten. This engineer submitted the same hydrometer to rectilinear calibration in a canal, and then to calibration on a revolving-arm, the length of which was only 0·619 metre; the result was that, with equal velocities of the centre of the hydrometer, the number of revolutions of the mill was a little greater in the second case than in the first, in accordance with the above theory.*

Lastly, the revolving-arm and the anemometer itself in moving carry with them a little air which is therefore not altogether motionless.† The instrument does not therefore move in a fluid completely at rest. If possible, one ought, consequently, to take into account in the results of calibration the true velocity of the air at the point through which the instrument passes. Attempts have been made to do this by placing in the immediate neighbourhood of the trajectory of the instrument experimented upon, a second anemometer, which was to determine this velocity. But the correction thus deduced would necessarily be greatly exaggerated, because this auxiliary anemometer receives an abrupt impulse every time that the revolving-arm passes before it, and is accordingly in the condition in which any irregularity of time produces the maximum of exaggeration in its indications. It may be maintained therefore that the correction that is introduced by some German experimenters does more harm than good.

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* *Annales des Ponts et Chaussées*, 1847, second half-year, page 337.

† See on this subject what the German authors say regarding what they call "mitwind." (1) Mr. Recknagel, *Annalen der Physik und Chemie*, 1880, vol. x, page 677; and (2) Mr. Grashof, *Theoretische Maschinenlehre*, vol. ii., page 163, and vol. iii., page 54.

In any case, it is easy to get rid of this correction. It would suffice if the revolving-arm were made very thin, and with its front edge brought to a cutting-edge. The amount of air carried by it would thus become negligible, as may be proved by the fixed anemometer, which is seen to no longer turn even when the revolving-arm passes quite close to it.

By observing the preceding precautions, calibration on the revolving-arm will certainly give results quite sufficiently accurate.

CONCLUSION.

In conclusion, it has been seen that the Pitot tube and mill or fan anemometers, calibrated by means of a revolving-arm or by rectilinear displacement, measure accurately the velocity of the fluid-current in which they are submerged, if this current is perfectly homogeneous and regular; that under opposite conditions, which unfortunately more frequently prevail, they give, as regards the mean velocity, indications which are always exaggerated, and are the more exaggerated the more marked the irregularity of the current itself.

The Pitot tube thus measures rather the quantity of mean motion in a given time, on the trajectory in which it is located. From this the mean velocity may be deduced with a certain amount of approximation, if the coefficient of irregularity is known.

As regards anemometers, they measure the mean quantity of motion in a given space in the case of liquids; and they would also measure it in the case of air, if the irregularity existed with regard only to space: but it also necessarily occurs with regard to time, and as the inertia of the mill plays a more important part the more rapid and abrupt the variations of velocity, the indications of the instrument have only a very complicated relation either to the mean velocity or to the quantity of mean motion.

We must, therefore, conclude that it will always be impossible to measure accurately the velocities of irregular air-currents by means of the Pitot tube, and still less by means of anemometers.

All that can be done is first of all to reduce to as low a point as possible the effect of the inertia of the mill by observing the conditions above laid down, namely, vanes inclined at an angle of 45 degrees and an exceedingly light moving wheel; and, secondly, by obtaining general data, at any rate approximate data, as to the amount of exaggeration to be expected in the conditions which are generally met with. As regards this latter point, everything still remains to be done. Experiments upon it would certainly be long and tedious, but not impossible, and assuredly would not be deficient in interest.

The influence of the inertia of the revolving parts should, on the other hand, have but very little effect in fan hydrometers; wherefore it may be affirmed that these instruments are more accurate than the Pitot tube, or its derivative the Darcy tube, for the measurement of currents of water, the velocities of which vary rapidly in time, as is notably the case in rivers and canals.

The equation for hydrometers and anemometers which ought to be employed for low velocities is:—

$$v = a + bn + \frac{c}{v},$$

which is of the second degree as regards v; a, b and c being three coefficients, of which the first, a, is generally very small and sometimes zero in the case of hydrometers, and of which the third is smaller the less the friction in the pivots and gearing of the apparatus.

For high velocities, the preceding equation does not appear to agree exactly with the results of calibration, which often produce a slightly sinuous curve, the cause of which appears to be due either to some important modification in the wave of displacement produced in the fluid by the passage of the hydrometer and its supports, or to a modification in the law of resistance of the fluid.

The general equation for fan meters for all velocities ought, therefore, rather to be written:—

$$bn = v - \frac{c}{v} - \frac{f(v)}{v},$$

$f(v)$ being the function of the resistance of the fluid, a function with regard to which our knowledge is still somewhat deficient.

NOTE BY THE AUTHOR.—Since the publication of the above paper, Mr. Epper has undertaken a very complete and thorough series of experiments, the results of which he has kindly communicated to the author. These allow the conclusions arrived at in the paper to be summarized exactly. Their object was chiefly to determine exactly what is the cause of the hump found by Mr. Epper to exist in the calibration curves of hydrometers. His results show that:—(1) the hump is due, as supposed by Mr. Amsler, to the wave produced by the arm carrying the hydrometer, and not, as suggested by the author, to any variation in the law of fluid resistance against the edge of the revolving vanes, and (2) it is important to reduce the edges of the revolving vanes to a cutting edge, which has the effect of diminishing the value of the coefficient a of the equation, and therefore of diminishing the minimum velocity at which the instrument can be put in motion.

PARIS, *May* 10*th*, 1899.

THE MINING INSTITUTE OF SCOTLAND.

ANNUAL GENERAL MEETING,

HELD IN THE HALL OF THE INSTITUTE, HAMILTON, APRIL 13TH, 1899.

MR. JAMES T. FORGIE, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The SECRETARY read the Report of the Council as follows:—

COUNCIL'S REPORT.

The Council, in presenting the twenty-first annual report, are pleased to make a statement of good progress for the past year to the Institute.

The membership compares with last year as follows:—

On the roll at April, 1898		466
Added during the year		37
		503
Died	3	
Retired	23	
Cut off through non-payment of subscriptions	9	
	—	35
On the roll at this date		468

As indicated in the last annual report, it was found that the income of the Institute from subscriptions was insufficient to meet the increased expenditure connected with the publication of the *Transactions*, which are of greater value than formerly; and the Council were constrained to advise that the rate of subscription should be increased. This was considered and agreed to at a special meeting of the Institute held in May last, and the rules were altered accordingly.

It was anticipated that more retirements than usual would take place during the year, on account of the increase in the rate of subscription; but it is gratifying to state that not so many have retired as was estimated.

The papers which, with discussions thereon, have been printed in the *Transactions* during the year are as follows:—

Address by the President upon "The Progress of Mining during the History of the Institute."
"Notes on a Water-Heater recently erected at Cadzow Colliery."
"Underground Steam-Appliances and Temperature of Strata at Niddrie Collieries."
"Timbering and Supporting Underground Workings."
"The Douglas Coal-field, Lanarkshire."
"Two Types of Electrical Coal-cutters."

The annual excursion to Birmingham in September, coincident with the meeting of The Institution of Mining Engineers there, afforded members an opportunity of visiting collieries and other works in that district, and was much appreciated by those who took part in it. The distance was too great for many of our members to attend.

But, in order to suit the convenience of members who could not go to meetings in the south, and to give variety to the year's proceedings two local excursions were arranged, one to Bannockburn colliery, belonging to the Alloa Coal Company, and the other to the power-station of the Glasgow District Subway Company. These were largely attended, and there was a fairly general expression of the desire for more of such excursions in the future.

Your delegate on the Corresponding Societies Committee of the British Association for the Advancement of Science was unable to attend the last annual meeting held in Bristol. Of the many subjects of investigation undertaken by the committees of the Association, the two that bear most closely upon the objects of this Institute are :—(1) The collection, preservation and systematic registration of photographs of geological interest; and (2) The recording of the rate of increase of underground temperature in various localities on dry land and under water.

One paper read during the year gave interesting particulars of underground temperature. The results of further investigation in these directions will be welcomed by the Council.

The donations received during the year were as follows :—

DONORS.	DONATIONS.
Mr. J. M. Ronaldson ...	H.M. Inspector's Report for West Scotland, 1897, (two copies). Report on the Drumpeller Colliery Accident (two copies). List of Mines in the United Kingdom, 1897. List of Plans of Abandoned Mines to December, 1897. District Statistics, 1897, part i. General Report and Statistics, 1897, part i.
Mr. Fred J. Rowan ...	Paper on Water-tube Boilers.

Additions are constantly being made to the library, by exchange with other Institutes and periodicals, and by purchase.

A new catalogue of the library is in preparation and will be issued shortly.

The Treasurer's accounts for the year show that financially the Institute is in a satisfactory condition.

There have been seven meetings of Council during the year.

The adoption of the report was agreed to unanimously.

The SECRETARY read the following abstract of the Treasurer's accounts for the year :—

THE TREASURER IN ACCOUNT WITH THE MINING INSTITUTE OF SCOTLAND

FOR THE SESSION 1898-99.

RECEIPTS.		£	s.	d.
To Balance brought forward		121	17	10
„ Subscriptions—				
1 Federated Member, Session 1897-98	at 31s. 6d.	1	11	6
1 „ „ „ „ ..	at 13s. 1d.	0	13	1
2 „ „ „ „ ...	at 21s. 0d.	2	2	0
1 Federated Life Member		25	0	0
1 Associate Life Member		15	15	0
(Additional) from a Life Member		10	0	0
160 Federated Members, Session 1898-99	at 42s. 0d.	336	0	0
193 „ „ „ „ ...	at 25s. 0d.	241	5	0
1 „ „ „ „ ...	at 21s. 0d.	1	1	0
19 Associate Members „ „ ...	at 42s. 0d.	39	18	0
1 „ „ „ „ ...	at 31s. 6d.	1	11	6
4 „ „ „ „ ...	at 25s. 0d.	5	0	0
14 Students „ „ ...	at 25s. 0d.	17	10	0
22 Non-Federated Members „ ...	at 21s. 0d.	23	2	0
18 „ „ „ ...	at 10s. 6d.	9	9	0
1 Federated Member, Session 1899-1900	at 26s. 5d.	1	6	5
1 „ „ „ „ ...	at 42s. 0d.	2	2	0
1 Associate Member „ „ ...	at 42s. 0d.	2	2	0
„ Donation		2	2	0
„ Repaid by The Institution of Mining Engineers ...		0	13	0
„ Transactions sold		0	17	3
„ Rents of Hall		2	8	6
„ Interest on Deposit Receipt		3	1	0
		£866	8	1

PAYMENTS.	£	s.	d.	£	s.	d.
By The Institution of Mining Engineers ...				456	12	0
„ Printing and Stationery				26	19	2
„ Books and Bookbinding				14	8	10
„ Rents of Halls				17	7	0
„ Gas and Assessments				2	15	4
„ Stamps, Carriages, Telegrams, etc. ...				11	5	6½
„ Book Case				7	0	0
„ Sundry Payments				3	10	8½
„ Cleaning Hall				6	6	0
„ Expenses of Council				31	9	0
„ Salaries				97	12	0
„ Balance in Bank	190	15	7			
„ „ in Treasurer's Hands	0	6	11			
				191	2	6
				£866	8	1

March 30th, 1899.—Examined, compared with vouchers, and found correct.

DAVID TODD, } AUDITORS
ROBERT WEIR, }

The following gentlemen were elected :—

Members—

Mr **Frederick Wilson Hurd**. Lynedoch, Prestwick.
Mr. **Arthur M'Gregor**, Limerigg Cottage, Slamannan.
Mr. **George Morrison**, Kepplehill and Stane Collieries, Shotts.
Mr. **William Ross**, 33½, Newton Street, Kilsyth.
Mr. **Henry Telfer**, Jun., Clydesdale, Uddingston.

ELECTION OF OFFICE-BEARERS.

The **President** declared the following office-bearers duly elected for the session 1899-1900 :—

President.

Mr. **James T. Forgie**, Bothwell Collieries, Bothwell.

Vice-Presidents.

Mr. **Charles T. Geddes**, 21, Young Street, Edinburgh.
Mr. **James Hamilton**, 208, St. Vincent Street. Glasgow.
Mr. **James Hastie**, Greenfield Colliery, Hamilton.
Mr. **James Wallace**, Wester Gartshore Colliery, Kirkintilloch.

Councillors.

Mr. **Thomas Arnott**, Fernbank Cottage, Newton.
Mr. **Adam Brown**, Allanton Colliery, Hamilton.
Mr. **Alex. Faulds**, Rochsolloch Colliery, Airdrie.
Mr. **James Hardie**, The Haugh, East Wemyss, Fifeshire.
Mr. **Douglas Jackson**, Coltness Iron Works, Newmains.
Mr. **John Menzies**, Auchinraith Colliery, Blantyre.
Mr. **Andrew Pearson**, Stonelaw Cottage, Rutherglen.
Mr. **Michael Ross**, Bog Colliery, Larkhall.
Mr. **Henry Rowan**, Hill of Beath Colliery, Crossgates.
Mr. **Thomas Thomson**, Eddlewood Colliery, Hamilton.
Mr. **Robert Weir**, Camp Colliery, Motherwell.
Mr. **James Wyper**, Townlands Colliery, Hamilton.

DISCUSSION ON MR. GEO. L. KERR'S PAPER ON "TIMBERING AND SUPPORTING UNDERGROUND WORKINGS."*

Mr. **Duncan Ferguson** (Blairadam) wrote that, having had 9 years' experience of the Aitken process of treating timber, and having used thousands of gears and props, he had never seen a single instance of either a gear or prop giving way, where untreated timber would not have done the same ; in short, he had never noticed that the Aitken process at all reduced the strength of timber. This, too, in face of the fact that he had used foreign timber in place of larch ; indeed, he now used no larch, and the saving on this head was great. While he did not dispute the correctness of Prof. Louis' figures regarding the strength of the Aitken-treated timber, he could not get any confirmation of them in his experience. During the many years that he had used the Aitken-treated timber not one piece had rotted, not one showed the slightest sign of decay, and all were as fresh as the day when they were put into the mine. When the timber was untreated, timber-men were continually renewing broken wood in a decayed state, especially in the return air-ways. During the last 3 years, he had had three spontaneous fires, and while beating back the fire with water-jets he found the timber standing inside. He removed one of the props for examination and found it black and hard, while untreated timber would have been entirely consumed. Had he not used the Aitken-treated timber, he would have been obliged to abandon one of the coal-seams now being worked.

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* *Trans. Inst. M.E.*, vol. xvi., pages 230 and 430.

Mr. G. R. **Thompson** (Glasgow) spoke in favour of the deputy system of timbering as practised in the Durham mines-inspection district.

Mr. A. **Pearson** (Rutherglen) said that the deputy system as now in vogue placed the responsibility on the miner, who had to timber his own place if the deputy was not in attendance.

Mr. J. **McVie** (Hamilton) could not see the force of paying a miner for timbering, work that another man had to do. He also asked what would become of the working-places in the event of the deputy being detained 3 hours, or even 1 hour? In support of Mr. D. Ferguson's statement regarding the Aitken process of treating timber for use in mines, he might state that in his 5 years' experience he had never seen the least indication of decay in any timber so treated. About 4 years ago, gears (every alternate one treated) were put in the main return airway of the No. 3 pit, Ell coal-seam, Cadzow colliery. About a year ago, all the untreated gears were replaced owing to decay. The treated timber is still in use, and in good condition. As regards the contention that the Aitken process reduced the strength of the timber, he had never seen anything to make him think that this was the case. Indeed, he had stopped using larch timber, and now used treated Scotch or foreign fir. The Aitken process was adopted at the Cadzow colliery in 1891, and all the treated timber was still quite fresh.

The **President** said that the deputy system had been tried only in the North of England. He further pointed out that the roadsman was supposed to help the miner, if the latter found any special difficulty in propping his place. He agreed with the remarks made by Mr. Pearson that the miner was not relieved of the responsibility of putting up timbering to protect himself in the absence of the deputy.

Mr. J. McVie said that, in his experience, they would require to get someone to timber a place before a miner would go into it.

The discussion was adjourned.

DISCUSSION ON MR. ROBERT WEIR'S PAPER ON "THE DOUGLAS COAL-FIELD, LANARKSHIRE."*

The President remarked that Mr. Weir's paper contained a description of a coal-field which had been for a long time past wrought on a very small scale, but in which, according to Mr. Weir, there was room for considerable development. Mr. Weir stated that the new colliery of the Coltness Iron Company "should well nigh exhaust all the workable coal in the Limestone measures of the district, and the quantity of available coal should not be far short of 15,000,000 tons." He wanted to know whether this statement was perfectly accurate, and whether this Coltness colliery would really exhaust the whole of the Limestone measures.

Mr. Weir having answered in the affirmative, the further discussion was adjourned.

The following paper by Mr. W. D. L. Hardie on "Machine-mining and Pick-mining Compared" was read as follows :—

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* *Trans. Inst. M.E.*, vol. xvi., page 436.

MACHINE-MINING AND PICK-MINING COMPARED.

By W. D. L. HARDIE.

The Galt coal-field is situated in Alberta, Canada, about 800 miles west of Winnipeg, 110 miles west of Dunmore on the Canadian Pacific Railway, and 66 miles north of the international boundary-line (49 degrees north latitude) between the Dominion of Canada and the United States of America. It is reached by a branch-line of the Canadian Pacific Railway, which runs from Dunmore to Lethbridge and is now being extended into British Columbia *via* Crow's Nest Pass. There is also a narrow-gauge railroad, 200 miles long, from Great Falls in Montana to Lethbridge in Canada.

The colliery of Lethbridge, as well as the town of Lethbridge with a population of about 2,000, are situated in the south-eastern corner of the Galt coal-field. The extent of this coal-field is not yet well defined, but it is known to be of immense area and belongs to Cretaceous or later times; and with many breaks stretches from Coahuila in the republic of Mexico to Athabasca in Canada.

The coal is a high-grade lignite, and by some engineers is classed as semi-bituminous. It is a free-burning coal and, all its qualities considered, is the best coal yet found in the North-West Territories for domestic and steam uses. It does not coke.

The Galt coal-field has a general northerly dip, but is so broken by faults running in all directions, with a throw of from 1 to 9 feet, that the general dip has but little bearing on the mining operations, further than the cost of cutting these faults.

When the Lethbridge colliery was opened, several years ago, the coal was got through the drifts opened near the bed of the Belly river (which lies about 300 feet below the prairie), and raised to the prairie-level over an incline plane 2,500 feet long. Some years ago, the drifts in the outcrop above high-water mark were worked out and recourse to sinking was the result. Four shafts were sunk on the prairie:—No. 1 shaft is worked out; No. 2 shaft was sunk on a very inferior piece of the coal-field; and Nos. 3 and 4 shafts were sunk into the very best body of the coal, in the neighbourhood of Lethbridge. No. 3 shaft is now producing most of the coal sold by the Alberta Railway and Coal Company. About 800 tons of lump coal is raised per day, and from 150 to 200 tons of fine coal, which is passed over different screens making nut-coal, pea-coal, and slack. The amount of fine coals from machine-running is about 10 per cent. less than from pick-mining.

The seam at No. 3 shaft lies 350 feet below the prairie, and has an average thickness of 52 inches of good coal. However, the section detailed in the Appendix shows that the thickness varies. The roof is a friable shale from 20 to 60 feet thick, and the strata above it are gravel, blue clay, yellow clay, and surface-loam, in the order mentioned. The bottom is an impure fire-clay, and where there is any water on it very large pillars of coal have to be left, to prevent squeezing on haulage-ways. The face and butt-cleats of the coal are well defined, and extend into the shale above, on the same parallels. The butt-entries run east-and-west, and the face-entries run north-and-south. The main-face cleats are about 9 inches apart. Coal is worked on the face in rooms 20 feet wide, and mined 4 to 4½ feet deep, it makes very large lumps. The texture of the coal is fairly strong, but it disintegrates when exposed long to atmospheric influences.

About 2 years ago, the management decided to change from pick-mining to machine-mining. After some investigation as to the most suitable machine for this seam, a plant of Sergeant coal-cutting machines was purchased. The writer has had 15 years' experience with Legg, Harrison and Sergeant coal-cutting machines, and consequently knew precisely where to get the best machine-men to start work, and how to put the plant into condition for production of coal. In less than 6 months pick-mining was suspended altogether without reducing the output. The mechanism of the Sergeant machine has been described in several papers published in Great Britain.

As a direct means of comparison, the tonnage from entry-driving by pick-mining was carefully observed for a period of 6 months, which showed that the average production was 2 tons per running yard. Taking this tonnage, and using the prices paid for pick-work, we obtain the following figures of the cost per ton for driving entries by pick-work:—

2 tons at 2s. 9·15d. per ton	5s. 6·31d.*
1 yard at 7s. 7·55d. „	7s. 7·55d.
	13s. 1·86d.

And 2 tons at 13s. 1·86d. equals 6s. 6·93d. per top of lump coal.

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* The prices in dollars and cents have been transposed into British money at 4·85 dollars to the pound sterling.

A careful record of the amount of lump coal taken from 1,000 feet of entry driven by machines showed that 3 tons per running yard were produced. No yardage is paid for machine-work. The dead-work is all included in the tonnage price. The cost is therefore :—

3 tons at 1s. 2·84d. per ton paid to machine-men and helpers ...	3s. 8·52d.
3 tons at 2s. 10·64d. ,, ,, loaders and shooters ...	8s. 7·92d.
	12s. 4·44d.

And 3 tons at 12s. 4·44d., equals 4s. 1·48d. per ton of lump coal. In the above estimate, only entry-work is compared, to show what the result would be if machines were used for entry-driving alone.

In pick-work, there were four classes of narrow work, namely, entry-driving, cross-cut driving, room-neck driving, and room-turning. In machine-work, there are three classes of narrow work, namely, entry-driving, room-neck driving, and room-turning. For the purpose of comparing the cost per ton of general development, a plan has been made showing the mode of working before the machines were introduced (Fig. 1, Plate II.), and another plan (Fig. 2, Plate II.) has been made showing the mode of working after their introduction. In both cases, a length of 1,320 feet by a width equal to the amount of ground developed by four parallel entries has been selected.

PICK-WORK.—OLD SYSTEM (FIG. 1, PLATE II.).

Class of Work.	Feet.	No.	Feet.	Yards.	Tons.	Tons.	s.	d.	Cost. £	s.	d.
Entries	1,320 ×	4 =	5,280 =	1,760	× 2 =	3,520	at 2	9·15 =	486	4	0
				1,760			at 7	7·55 =	671	7	4
Entry cross-cuts	35 ×	44 =	1,540 =	513⅓	× 1 =	513	at 2	9·15 =	70	17	2
				513⅓			at 5	1·86 =	132	4	6
Room-necks ...	30 ×	176 =	5,280 =	1,760	× 2 =	3,520	at 3	1·11 =	544	5	7
				1,760			at 5	1·86 =	453	12	9
Room-turnings...	—	176	—	—		—	at 24	8·92 =	217	14	10
				4,033⅓		7,553			2,576	6	2

And 7,553 tons at £2,576 6s. 2d., equals 6s. 9·6d. per ton of lump coal.

MACHINE-WORK.—OLD SYSTEM (FIG. 1, PLATE II.).

Class of Work.	Feet.	No.	Feet.	Yards.	Tons.	Tons.	s.	d.	Cost. £	s.	d.
Entries	1,320	4 =	5,280 =	1,760	× 3	= 5,280	at 4	1·48 =	1,088	11	2
Entry cross-cuts	35 ×	44 =	1,540 =	513	× 2·7 =	1,385	at 4	1·48 =	285	10	9
Room-necks ...	30 ×	176 =	5,280 =	1,760	× 2·7 =	4,752	at 4	1·48 =	979	14	0
Room-turnings ..	—	176	—	—		—	at 16	5·94 =	145	3	4
				4,033		11,417			2,498	19	3

And 11.417 tons at £2,498 19s. 3d., equals 4s. 4·53d. per ton of lump coal.

The above system had always given trouble, inasmuch as it did not give the requisite size in entry-stumps to maintain the haulage-ways in good condition, and it was abandoned for the system shown in Fig. 2 (Plate II.).

MACHINE-WORK.—NEW SYSTEM (FIG. 2, PLATE II.).

									Cost.		
Class of Work.	Feet.	No.	Feet.	Yards.	Tons.	Tons.	s.	d.	£	s.	d.
Entries	1,320 ×	4 =	5,280 =	1,760	× 3 =	5,280	at 4	1·48 =	1,088	11	2
Entry cross-cuts	50 ×	20 =	1,000 =	333⅓	× 2·7 =	900	at 4	1·48 =	185	11	0
Crosscut-necks	15 ×	80 =	1,200 =	400	× 2·7 =	1,080	at 4	1·48 =	222	13	2
Room-necks ...	15 ×	84 =	1,260 =	420	2·7 =	1,134	at 4	1·48 =	233	15	10
Room-turnings ..	—	124...		(regular)			at 16	5·95 =	164	19	2
„ „ ...	—	76...		(splitting pillars)							
				2,913⅓		8,394			1,895	10	4

And 8,394 tons at £1,895 10s. 4d., equals 4s. 6·19d. per ton of lump coal. But the old system develops an area the width of which is 1,080 feet, against a width of 982 feet in the new system; therefore 1,080 feet : 982 feet = 4s. 6·19d. : 4s. 11·88d. per ton of lump coal.

PICK-WORK.—NEW SYSTEM (FIG. 2, PLATE II.).

									Cost.		
Class of Work.	Feet.	No.	Feet.	Yards.	Tons.	Tons.	s.	d.	£	s.	d.
Entries	1,320 ×	4 =	5,280 =	1,760 ×	2 =	3,520	at 2	9·15 =	486	4	0
				1,760			at 7	7·55 =	671	7	4
Entry cross-cuts...	50 ×	20 =	1,000 =	333 ×	1 =	333	at 2	9·15 =	45	19	11
				333			at 5	1·86 =	85	16	7
Crosscut-necks ...	15 ×	80 =	1,200 =	400 ×	2 =	800	at 3	1·11 =	123	14	0
				400			at 5	1·86 =	103	2	0
Room-necks ...	15 ×	84 =	1,260 =	420 ×	2 =	840	at 3	1·11 =	129	17	9
				420			at 5	1·86 =	108	5	6
Room-turnings ...	—	200	—	—		—	at 24	8·92 =	247	8	8
				2,913		5,493			2,001	15	9

And 5,493 tons at £2,001 15s. 9d., equals 7s. 3·46d. per ton of lump coal.

Machine-work as shown in Fig. 1 (Plate II.) has not been put into practice, nor has pick-work in Fig. 2 ever been put into practice; and the actual comparison is really between pick-work as shown in Fig. 1 and machine-work as shown in Fig. 2 (Plate II.).

It is worth while to notice that very little mining (holing) was done in the narrow work driven by pick-work. The coal was smashed out of the solid by powder, hence the very small tonnage of lump coal per yard of entry-work. The machines hole in the fire-clay under the coal to a depth of 4½ feet, and two rib-shots bring the whole down in very large lumps.

Up to this point, it must be borne in mind that we have only been comparing narrow work. A comparison of wide work will now be given.

PICK-WORK (WIDE PLACES).

A careful record kept over a long period shows that a cut 15 feet by 4 feet gave a little less than 8 tons of lump coal. We will here assume 8 tons :—

	Cost.
8 tons at 3s. 1·11d. paid to miners	£1 4s. 8·8d.
1¼ yards at 1s. 8·78d. „	0 2s. 3·7d.
	£1 7s. 0·5d.

And 8 tons at £1 7s. 0·5d., equals 3s. 4·6d. per ton of lump coal.

MACHINE-WORK (WIDE PLACES).

As before, assume that a cut 15 feet by 4 feet gives 8 tons of lump coal :—

8 tons at 0s. 9·9d. paid machine-men and helpers	6s. 7·2d.
8 tons at 1s. 7·8d. paid coal-loaders and shooters	13s. 2·4d.
	19s. 9·6d.

And 8 tons at 19s. 9·6d., equals 2s. 5·69d. per ton of lump coal.

Although pick-work turns out about the same amount of coal as machine-work in wide places, that is, places over 8 feet wide, pick-work coal does not look so well on railroad cars as machine-coal, and the lumps from pick-work are smaller. If a 1¼ inches mesh were used in the screens instead of a ⅝ inch mesh, the percentage of lump coal from pick-work would fall short of that due to machine-work.

In the Appendix, it will be noticed that there is a band of fire-clay between the upper and lower bench of the coal-seam, and this sometimes turns into bone-coal. Where the clay-band was present, the miners holed in it, but when absent the coal was blasted out of the solid. The machines mine under the coal, in the bone-coal and fire-clay, in rooms as well as in entries.

Costs.—The following statement shows the amount invested in the plant which is capable of mining 720 tons of lump coal per day. The average capacity of a machine is about 30 tons in a working day of 9 hours. The machines are worked double-turn, and as some machines will always be off for repair or other causes the work of 24 machines may be reckoned upon.

	£	s.	d.
1 air-compressor, Norwalk compound, cylinders 20 inches in diameter by 24 inches stroke	721	14	0
1 air-compressor, Ingersoll-Sergeant, cylinders 24 inches in diameter by 30 inches stroke	1,009	16	9
2 tubular boilers, each of 100 horsepower	464	19	7
5 air-receivers, of different sizes	112	3	5
14 Sergeant mining machines	933	17	7
Foundation for air-compressors	206	4	0
6,000 feet of 5 inches pipe	395	18	1
10,000 feet of 2½ inches pipe	371	3	2
30,000 feet of 1¼ inches pipe...	510	6	10
150 key-valves	54	0	5
General pipe-fittings	206	4	0
15 lengths of machine-hose	123	14	5
Labour connected with plant, material for erecting boiler-walls, houses, etc.	1,134	2	0
	6,244	4	3

In addition to the value of the plant, there is an operating expense in excess of the operating cost by pick-work: it is estimated as follows :—

	Per Month. £	s.	d.
Repair of machines	14	8	2
3 firemen	38	7	2
1 blacksmith	15	9	3
1 machinist	15	9	3
1 pipe-man and boy	18	11	2
1 pick-boy	4	2	6
400 feet of 5 inches pipe	26	7	10
1,000 feet of 2½ inches pipe	37	2	4
25 new machine-picks	10	6	2
Extra pipe-laying	10	6	2
Interest on £6,244 4s. 3d. at 10 per cent.	62	8	10
Depreciation on £6,244 4s. 3d. at 8⅓ per cent.	52	0	9
Pea-coal	39	8	3
Total working expenses	344	7	10

Everything considered, it is not safe to reckon on more than 24 working-days in each calendar month which would be equal to 17,280 tons per month, therefore 17,280 tons at £344 7s. 10d, equals 4·78d. per ton of lump coal.

Narrow-work coal will represent about $\frac{1}{20}$ of the total output, therefore :—

	£	s.	d.
864 tons, $\frac{1}{20}$ of 17,280 tons of entry coal, at 4s. 11·88d.	215	11	4
16,416 tons of room coal at 2s. 5·69d.	2,030	15	11
17,280	2,246	7	3

And 17,280 tons at £2,246 7s. 3d. equals 2s. 7·2d. per ton, and if the working expenses be added of 4·78d. per ton, the cost of lump coal from machines is 2s. 11·98d. per ton.

Taking the same proportions of tonnage for pick-work we have

	£	s.	d.
864 tons of entry coal at 6s. 9·6d.	293	15	3
16,416 tons of room coal at 3s. 4·6d.	2,777	0	9
17,280	3,070	16	0

And 17,280 tons at £3,070 16s. equals 3s. 6·6d. per ton of lump coal by pick-work.

The saving is (3s. 6·6d. — 2s. 11·98d. =) 6·62d. per ton of lump coal, in favour of machines.

In many instances in America, the elasticity of the system is a greater consideration than the saving per ton over pick-work. When trade fluctuates, with pick-work the facilities underground must always be equal to the largest possible demand, which often entails expense that is a drag in slack seasons. The machine system is very elastic.

The average earnings of all men connected directly with coal-getting are considerably greater in machine-mining than in pick-mining. During the 15 years that the writer has been connected with machine-mining he has never known of one instance where a miner who had become a good machine-runner voluntarily went back to pick-work. There are two good reasons for this, namely, the work is not so arduous, and wages are higher. It must be borne in mind that machine-running is considered as skilled labour, and the wages are always higher for this class of work than for coal-loading, shooting, etc.

Although machine-running is classed as skilled labour it is scarcely entitled to this classification because the knack of running a machine can be acquired by any intelligent miner within 6 months, that is, a man may begin as a scraper (machine-runner's helper), and by only taking turns at running may become proficient in 6 months.

Of the 30 available machine-men, only 8 of them ever operated machines before coming here. The weight of the man does not count for much, and many men weighing less than 150 pounds do as good work and as much of it as men weighing 225 pounds. We hear a good deal about machines shaking runners to pieces, but there is no foundation for such statements. When a man becomes proficient, a light loose grip of the machine and a small pressure on the foot-block enable the runner to handle the machine at will, where the cutting is not exceedingly hard.

There is one factor that enters largely into the question of the introduction of machines and that is "labour." Any man can shovel coal: consequently, to get tonnage, only skilled runners and a few experienced men to do the shooting, propping, etc., are required, while the bulk of the work can be done by unskilled labour. Many men in America make a living in coal-mines, who never dreamt of entering one until they were middle-aged.

Air-compressors.—It is a common practice in America to multiply the area of the air-piston by the distance it travels per minute, and state the result as the free-air capacity of the air-compressor. The free-air capacity of the compressor divided by the number of atmospheres will give the amount of air after compression, and this amount must be reduced by allowances for altitude above sea-level, dead-space, piston and valve leakages, etc.

An air-compressing cylinder, 24 inches in diameter by 30 inches stroke, at 80 revolutions per minute, will inhale 1,256 cubic feet of free air per minute, from which 9 per cent should be allowed for altitude, as the machine is about 3,000 feet above sea-level, and 15 per cent. for dead-space, valve-leakage, etc., leaving 972 cubic feet as the free-air capacity of the compressor. The quantity of compressed air delivered into the air-receiver at 75 pounds per square inch will be (972 cubic feet of free air ÷ 6 atmospheres =) 162 cubic feet of air compressed to 75 pounds per square inch.

An Ingersoll-Sergeant coal-mining machine, with a 4 inches cylinder of 11 inches stroke, running at 200 strokes per minute will use 16 cubic feet of air per minute. Consequently, the air-compressor is capable of running only 10 machines, provided that they are planted close up to it and that there is no reduction of volume due to fall of temperature between the air-receiver and the points at which the machines use the air. With large main-pipes, and judiciously selected branch-pipes, the reduction of pressure will not be very considerable. In the present case it has at no time exceeded 10 pounds per square inch with the machine running on 500 feet of 1¼ inches pipe connected with 500 feet of 2½ inches pipe connected on 1,500 feet of 5 inches pipe. There are many elbows on to the line.

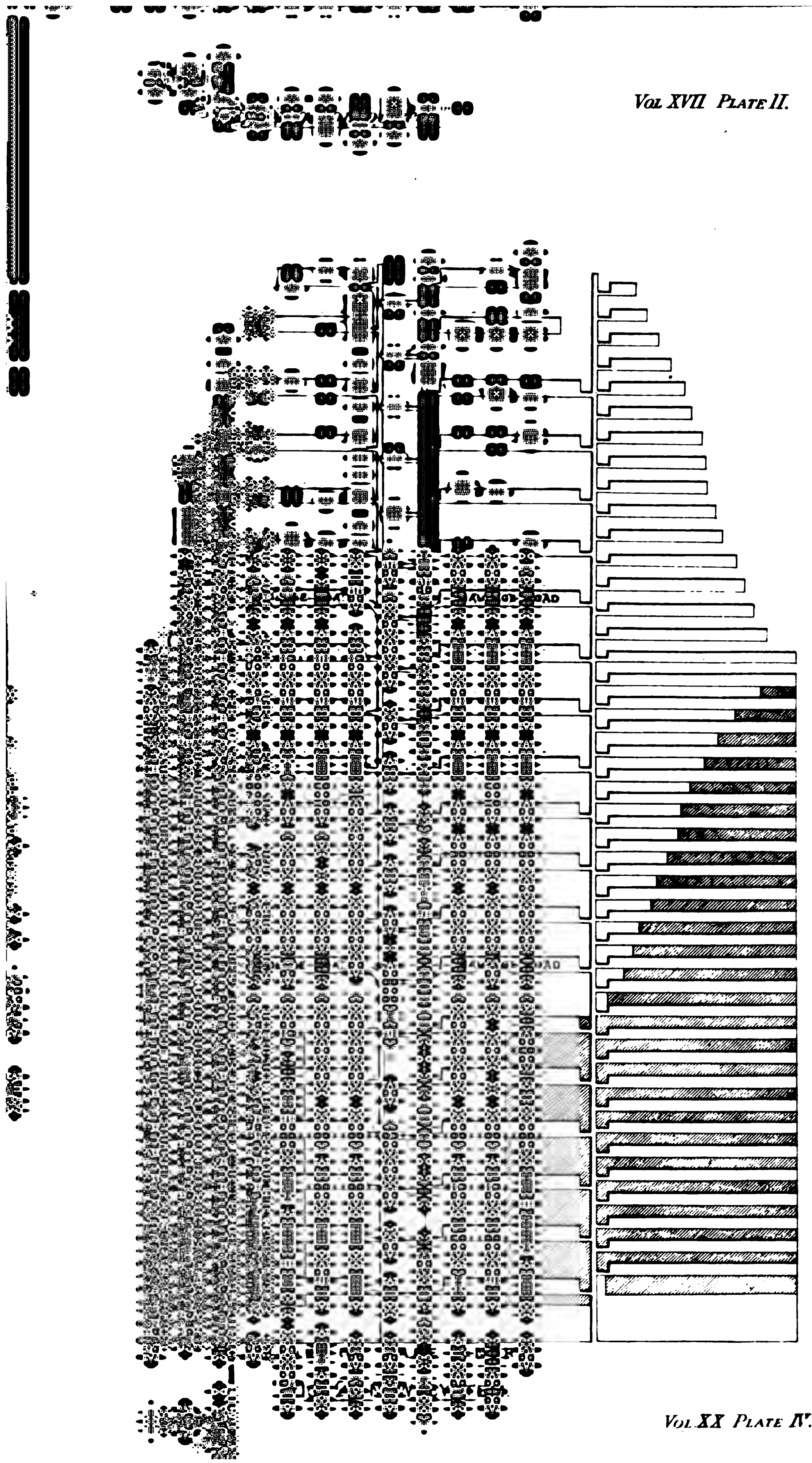
The reduction of volume of compressed air due to fall of temperature between the air-receiver and the point where the machines use the air is a very important factor. The Ingersoll air-compressor delivers the compressed air into its receiver at a temperature of 228° Fahr., which falls to about 50° Fahr. in the mine near the point where the machines use the air.

After-coolers are being put in, not with the view of increasing the capacity of the machine, but of reducing the temperature in the pipes, for avoiding ignition of oil in receiver, and possibly avoiding an explosion. The receiver has been filled with flame at least once. So far as the writer's experience goes, the Ingersoll-Sergeant compressor delivers the air into its receiver at a higher temperature than does the Norwalk compound compressor.

The following statement shows the effect of using the after-cooler:—

	Before the After-cooler was erected.	After the After-cooler was erected.
Air-compressor running at, revolutions per minute	100	106
Barometrical pressure in inches	28·2	28·2
Pressure in air-receiver at compressor, pounds per square inch	67	66
Temperature of compressed air in air-receiver at compressor, degrees Fahr.	228	104
Temperature of free air at piston-inlet, degrees Fahr.... ...	47	55
,, compressed air in mine, at end of pipe, degrees Fahr.	50	55·4
Pressure of compressed air in mine, at end of pipe, pounds per square inch	58	58
Temperature of the working-places in the mine, degrees Fahr.	68	68

Vol. XVII Plate II.



Vol. XX Plate IV.

The writer is aware that comparisons based on the high prices paid in the Far West will not be of much advantage to those who are dealing with lower prices and wages generally. Nevertheless, the writer hopes that his paper will at least prove interesting, that it may lead to a further discussion of the subject and may bring out something of decided advantage to all the members.

APPENDIX.—SECTIONS OF COAL-SEAM.

Districts.	North.		East.		South.		West.	
	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.
Following shale	0	6	0	8	0	8	0	6
COAL, *Upper Coal Bench* ...	1	5	1	8	1	4	1	9
Fire-clay	0	2	—		—		0	3
COAL, *Bone Coal*	—		0	4	0	6	—	
COAL, *Bottom Coal Bench* ...	2	10	2	4	2	0	2	3
COAL, *Bone Coal*	0	6	0	8	0	9	0	9
Bottom, clay...	0	8	0	6	0	9	0	7
Totals	6	1	6	2	6	0	6	1

CHESTERFIELD AND MIDLAND COUNTIES INSTITUTION OF ENGINEERS;

AND

MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.

JOINT MEETING,

HELD IN THE ROOMS OF THE LITERARY AND PHILOSOPHICAL SOCIETY,
SHEFFIELD, MARCH 24TH, 1899.

MR. W. D. HOLFORD, PRESIDENT OF THE CHESTERFIELD AND MIDLAND COUNTIES INSTITUTION OF ENGINEERS, IN THE CHAIR.

The following gentlemen, having been previously nominated, were elected members of the Midland Institute of Mining, Civil and Mechanical Engineers :—

MEMBERS—

Mr. JOSEPH ELSTOB, Assistant Colliery Manager, Beech Grove, Whitwood, Normanton.

Mr. JOSHUA CARNELLEY LODGE, Colliery Owner, Ryhill Main Colliery, Barnsley.

Mr. GEORGE SPENCER read the following paper on "The Application of Liquefied Carbonic Acid Gas to Underground Fires" :—

THE APPLICATION OF LIQUEFIED CARBONIC ACID GAS TO UNDERGROUND FIRES.

By GEORGE SPENCER.

Several years ago, in studying the best methods of extinguishing gob-fires, the writer conceived the idea that if a gas in itself non-combustible and not supporting combustion could be obtained in any required quantity at a cheap rate, and this ideal gas be applied to any fire, it would prove to be a convenient way of extinguishing gob-fires. About the same time, liquefied carbon dioxide came under his notice, consequently he decided to give it a trial, and the opportunity came sooner than he desired.

At a colliery with which the writer was connected a fire occurred in a heading, as the result of a fall of roof and sides on steam-pipes. The heading was built off with as little delay as possible, but notwithstanding all efforts to shut out the air, sufficient reached the seat of fire to keep it burning slowly. It was therefore decided to apply carbon dioxide, and for this purpose six cylinders of liquefied gas were connected in the manner described hereafter, and the contents discharged through a hole in one of the stoppings. From a distant stopping it was ascertained that the gas had diffused throughout the headings; from that time the heat abated, and no trouble whatever was subsequently experienced.

Liquefied carbon dioxide is supplied in drawn steel cylinders of three sizes, namely, B size, containing 20 lbs. ; C size, containing 30 lbs. ; and D size, containing 36 lbs. The gas is collected from the fermentation-vats of breweries, and liquefied by means of pressure assisted by low temperature. The writer found the C size convenient for use, but the smaller size would be found more suitable for application in confined places.

The C size, when empty, weighs about 90 lbs, and measures 43 inches in height by 7 inches in diameter. The bottom is made concave, like an ordinary bottle, and the top is drawn to a neck, in which a screw-plug is fitted. A detached coupling is supplied to screw to the neck, by means of which the screw-plug is turned on or off, and the escape of gas regulated.

The pressure of the gas in the cylinders varies according to the temperature. If, for instance, the cylinder and its contents have a temperature of 32° Fahr., the corresponding pressure will be 509 lbs. per square inch ; with 50°, the corresponding pressure is 664 lbs. per square inch ; at 68°, 849 lbs. ; and at 86°, 1,065 lbs.

One pound of the liquid will produce 8 cubic feet of carbon dioxide at atmospheric pressure and temperature. The temperature of the escaping gas is, however, much below freezing-point, which is a great advantage in cooling down the heated mass after extinction. Any number of cylinders may be connected to a main pipe, to give a continuous flow or a large quantity. The writer has connected six cylinders at one time to a 2 inches pipe, with ¾ inch branches placed at intervals of 1 foot. The cylinders may be placed upright and connected to the ¾ inch branches by short pieces of flexible tube, and from the end of the main pipe a flexible tube of larger diameter may be carried to any desired point. By means of a small tap at each branch, the connexion between the branch and the corresponding cylinder may be closed and another substituted as required. The whole series of cylinders, therefore, is under perfect control, and a continuous flow of gas is readily maintained.

The liquid carbon dioxide costs 2d. per lb., delivered in quantities of not less than 300 lbs., or 10 cylinders of C size.

According to Dr. F. Clowes,[*] air containing 15 per cent. of carbon dioxide will extinguish flame, and probably the same mixture will fail to support the combustion of the material usually met with in underground fires. To extinguish a fire (whether above or belowground), all that is necessary is to keep it immersed in a bath of an extinctive mixture of the above proportions, for a length of time sufficient to allow the mass to cool down. Such a mixture may be obtained by means of liquefied carbon dioxide at a cost of 1d. per cubic yard, exclusive of labour. It must, however, be borne in mind that in practice a large amount of carbon dioxide is given off from a burning mass, so that the figures quoted may be regarded as the maximum in estimating the cost of the process.

The rate of discharge of the gas varies greatly according to the surrounding temperature. During evaporation, intense cold is produced, and the valves are partly closed by the frozen gas. To increase the rate of discharge, the cylinders are sometimes laid on their side, and the liquid gas slowly discharged into the pipe. In some cases, a jet of steam may be directed upon the valve of the cylinder, so as to prevent the formation of solid carbon dioxide and to accelerate the discharge of the gas. The cylinder may also be immersed in a hot-water bath, but care should be taken not to apply too much heat to the cylinder itself, as the pressure increases rapidly with the rise of temperature.

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[*] *Trans. Inst. M.E.*, 1894, vol. vii., page 420.

In applying liquefied carbon dioxide to extinguish gob-fires, the writer considers that, where circumstances will permit, water would greatly assist in cooling down the heated mass, owing to its great specific heat, and if the situation be such that the water can be evaporated into steam.

It is not claimed that the method described can be successfully applied to all fires, but there are undoubtedly many cases which might be so treated. In case of fire on shipboard, the use of this gas would no doubt prove invaluable, as it could be quickly applied, and would not cause the same damage to cargoes as water.

Mr. M. H. MILLS (Mansfield) remarked that a fall of roof and sides (as mentioned in the paper) would not cause fire if it fell on a steam-pipe. Carbonic acid gas would be dangerous to use in the mines. Mr. Spencer had brought a most important matter before the members, and if this gas could be utilized in the form of spray or in some other way it would be useful and valuable.

Mr. A. S. DOUGLAS (Hucknall Torkard) said that if Mr. Spencer's suggestion could be adopted and the fire kept immersed in a bath of the gaseous mixture until it cooled down, they would soon put an end to gob-fires. Unfortunately, although they might close off the place and pack it round so as to shut off air, yet there was always sufficient leakage of air to keep the fire burning. He knew of a fire which had been burning for 5 years. A pipe was placed in a stopping, and the gas which issued would extinguish a safety-lamp. In this place, which was not exactly goaf, the resulting gases were able to extinguish flame, but they did not extinguish the gob-fire. Prof. Vivian Lewes had analysed the gases from a gob-fire: he found that every 100 parts of gas contained carbon dioxide, 13·15; carbon monoxide, 4·00; oxygen, 1·31; nitrogen, 76·44; and hydrocarbon gases, 5·10; and he thought that the 1·31 per cent. of oxygen was enough to keep a gob-fire alive. He (Mr. Douglas) did not believe that the injection of carbonic acid would extinguish a gob-fire. On shipboard it might be usefully employed, but he did not see how they could safely and efficiently apply it in a pit to extinguish underground fires.

Mr. **Geo. Spencer** said that, when the fall occurred, sufficient heat was generated from the coal and the steam-pipes to cause fire. There was no danger in using carbonic acid gas, as the volume of gas was not great. He did not agree with Mr. Douglas that it was impossible to extinguish a gob-fire by injecting carbonic acid gas. If the gas were applied on the intake side of the fire there was a possibility of the fire being put out.

Mr. W. H. **Chambers** said that unfortunately he had a gob-fire in one of the pits with which he was connected, and for the last 16 years he had had an average of one a year. Recently, a fall occurred when they were working at a fire, and the liberated gas passed over a fire, whose existence was previously unknown and caused an explosion which resulted in two workmen being so seriously burnt that they died from their injuries. There was great difficulty in dealing with fires, as they always originated in the broken strata of the goaf, where air was freely admitted through the fissures. When air could get through a fallen goaf, but not in sufficient quantities to cool down and carry away the heat which was given off during the oxidation of combustible matter, the fire gradually got into a state of incandescence, and afterwards began to burn. It would be very difficult to confine carbon dioxide in such areas. One fire had been walled round by brickwork and by wax-walls (as was practised in Warwickshire and Leicestershire), but all these palliatives had always proved ineffectual. Many years ago, the use of carbon dioxide was tried in the Parkgate coal-seam, in the Rotherham district, but although the district was filled for several months with this gas, when the experiment was suspended and air was re-admitted, combustion started again as vigorously as before. It was found that the combustible matter remained as it was before the gas was applied, and the condition of the fire was just the same after the gas was removed as it was before. He should be very glad if some means could be devised of applying carbonic acid gas, so as to stop combustion for such a time that the material might cool down ; but it seemed to him that the conditions under which the fire originated would remain, and after the restraining gas was withdrawn, when air was re-admitted, the fire would burst out. Where there was a bad roof and open breaks, there was nothing so effectual as isolating the fire with roads, to reduce the temperature as much as possible, and to dig out the red-hot material.

Mr. A. H. **Stokes** (H.M. Inspector of Mines) agreed with the last paragraph, in which the writer stated that there were undoubtedly cases in which the method would be of value; but he thought that in other cases it would probably do more harm than good. A fire in a heading could be dealt with by erecting a stopping, and allowing it to become gradually deadened by its own gases. The best remedy for an underground fire was to dig out the red-hot material, if possible; for if it were isolated by brick-walls or clay-walls, or sand, the source of heat was only buried and would probably burst out again at some future date. In the case of a fire in a roadway, which they could not get at, a bottle or two of carbonic acid might extinguish the flame, until they could dig it out. There were cases in which it could be used, but it might cause danger, if they had life on the other side, in the return air, as they would be filling the atmosphere with irrespirable gases.

Mr. H. B. **Nash** (Barnsley) said that it was almost impossible to extinguish an underground fire, unless the fire could be drowned or dug out.

Mr. Geo. **Spencer** said that he fully recognized the difficulties of applying the method to the cases quoted by Mr. Chambers. It was not sufficient to arrest combustion, which this gas would do, but the heat must be removed. It would not be applicable in every case, but if the fire was immersed in a bath of carbonic acid, the heat might be got rid of afterwards. It would be idle to propose that this gas should be applied in such quantities as to remove all the heat in the imprisoned fire, as it would be too costly.

The **Chairman** moved a vote of thanks to Mr. Spencer for his paper.

Mr. W. H. **Chambers**, in seconding the vote of thanks, said that the subject was one which demanded close attention, and the members were indebted to Mr. Spencer for his suggestions.

The resolution was carried.

DISCUSSION ON MR. G. L. KERR'S PAPER ON "TIMBERING AND SUPPORTING UNDERGROUND WORKINGS."*

Mr. A. H. **Stokes** (H.M. Inspector of Mines) said that the question of timbering and falls of roof ought to command the attention of every member, as a large percentage of the deaths in mines occurred from falls. Sometimes a working-place was found with a long distance of unsupported roof, which the stallman said was as safe as his bedroom;

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* *Trans. Inst. M.E.*, vol. xvi., pages 230 and 430; and vol. xvii., page 168.

and that occasionally was the place where an accident occurred. If each manager made a Special Rule that props or bars should not exceed a certain distance apart (which would vary in every mine), it would reduce the list of deaths from falls. A rule was in force in the Midland mines-inspection district that a man should not withdraw a prop except by a ringer-and-chain; and he never could understand why workmen should try to remove props, on which the roof was resting, by standing under such roof and striking the props with a hammer, instead of drawing it in safety by means of the ringer-and-chain. The rule should be strictly enforced in every working-place, that timber with weight upon it should be withdrawn only by the ringer-and-chain. It should also be an invariable rule that men who were sent to repair or rip a road should, before anything was touched, set middle or catch-props in the roadway, so that in case of a fall the man would have a chance of escape.

Mr. H. B. Nash (Barnsley) said that, if the workmen would comply with the Coal-mines Regulation Acts and carry out the instructions given to them by the officials, one half of the accidents which happened would be prevented. No colliery-official would ask a workman to take out a prop without ordering him to use the dog-and-chain or ringer-and-chain, and to protect himself by setting liner-props nearer the face before beginning to take out the others, so that should a fall occur it could not extend in his direction. It was an universal rule to tell men most carefully, whenever they went into a roadway, to renew bars, etc., to set middle-props before they took out one. The instructions given by colliery-managers agreed with Mr. Stokes' recommendations, but there was difficulty in inducing workmen to comply with official instructions.

Mr. A. H. Stokes said that the rules might be enforced by better supervision, carried out methodically, and if a man was caught in a breach of rule he should be dealt with by the authorities. Middle-props should be set, not only when taking out bars but also when ripping roadways (where there were no bars whatever), so that the roof should not come down farther than was anticipated. There was a difference between an instruction and a Special Rule: there was no penal punishment for non-compliance with instructions, but for breach of a Special Rule the man could be taken before the magistrates. He suggested that such instructions might be embodied in a Special Rule, so as to give the manager and officials power to enforce them.

Mr. W. H. **Chambers** said that, at the collieries under his charge, he had bye-laws providing that the distance between props should not exceed 3 feet in any direction. At most collieries, ringers-and-chains were provided for the removal of timber, but the difficulty was to make the men use them. They could not enforce a hard-and-fast-rule that all props must be withdrawn with the ringer-and-chain, but the men were required to use them as much as possible. In a case at the Nunnery colliery, a deputy spent some time in a place seeing that a bar was set, to make the place secure for the men to go on with their work; but when he left the place a filler knocked it out, filled his coal, the roof fell on the top of him, and he obtained compensation. Every care was taken as to timbering in the roads by appointing a chargeman with every gang of men, to see that props and bars were set when wanted, so that they were protected in their work.

Mr. A. H. **Stokes** said that he did not suggest that there should be one Special Rule fixing an uniform distance for the United Kingdom, but that every manager should fix the distance applicable to each seam in the mines under his charge, to be enforced by a Special Rule. The Act said that Special Rules should be framed for the conduct and guidance of the workmen, and it was their own fault if they were not properly drawn up.

Mr. **George L. Kerr** (Glasgow) wrote that he agreed with Mr. A. H. Stokes in his remarks both as to props being set at certain specified distances apart, and also as to the drawing of timber in pillar-workings. Safety could be secured without further Acts of Parliament by a stricter enforcement of those now in force. The firemen or deputies ought to have power to compel the workmen, under a penalty, to set props at specified distances apart, whether the roof be good or not. At the present time, the workmen were left almost entirely to their own discretion as to the setting of timber, and were under no penalty for not setting props at the proper time and place. While he was against the timbering in the walls being set by deputies, the workmen at the face ought to be strictly supervised in this department of work, either by deputies or firemen. In the mines of Scotland, where pillar-working is customary, it may surprise members to hear that the whole of the timber is withdrawn by striking it out with hammers, and he (Mr. Kerr) was not aware of a single colliery that used any special apparatus, such as a ringer-and-chain. He recommended that the removal of props in pillar-workings should be carried out by a special class of men, and not by the collier, as it required some skill and was dangerous, especially when the props were taken out by a hammer. The rule adopted at the collieries referred to by Mr. W. H. Chambers seemed to be in the right direction; but it would be difficult to make any hard-and-fast Special Rule applicable to all collieries, as the conditions of roof and sides varied so much in different parts of the country.

The **Chairman** said that at present too much responsibility was thrown upon managers and too little upon the workmen.

The following paper on "The Safety of Modern Mining Explosives, with Special Reference to Methods of Testing," by Mr. L. T. O'Shea, was read:—

THE SAFETY OF MODERN MINING EXPLOSIVES, WITH SPECIAL REFERENCE TO METHODS OF TESTING.

BY L. T. O'SHEA.

In testing explosives for safety in coal-mines the object should be not only to determine the relative safety of the explosives that are placed at the disposal of the mining industry, but also, if possible, to determine the conditions upon which the safety depends. Once these conditions are established, not only will mining-engineers have a means of deciding what explosives to use, but manufacturers especially will have some means to guide them in their endeavours to produce explosives suitable for mining purposes.

At present, however, the exact conditions are unknown, and there appears but little disposition in Great Britain to assist in solving the question, but on the Continent experiments of a more or less systematic character have been and are being carried out. The subject is of considerable importance to the coal-mining industry, especially in view of recent legislation, and the writer feels that no apology is necessary for introducing it to the notice of the members. Before discussing the actual methods of testing that are in practice, it is advisable to consider the state of knowledge with regard to the safety of explosives when used in explosive atmospheres, and at the outset it is necessary to define what is meant by the term "safety," as applied to explosives used in coal-mines. In the first instance, it refers to the inability of explosives on detonation to ignite the inflammable substances met with in a mine's atmosphere, and the oft-quoted definition that an absolutely safe explosive is one that will not ignite the most inflammable mixtures of gas and air, dust and air, or gas, dust and air, is, like Euclid's definition of a point, purely ideal. It is highly improbable that a body, possessing properties which at present characterize explosives, will be found to satisfy it. Consequently, the term "safe," as applied to explosives, can only be taken as relative, and the safest explosive is that which, under the most dangerous conditions of ordinary working, shows the least tendency to ignite dust or gas.

With the object of arriving at some conclusion as to the present knowledge of the conditions that determine the relative safety of explosives, it is proposed to discuss the results of recent experiments. It must, however, be confessed that our knowledge is very imperfect in spite of the vast amount of work that has been done; but, although the results are in many cases so conflicting that it may seem hopeless to reconcile them, still some important facts have been established, from which it is believed that it may be possible to arrive at the best method to be adopted for testing explosives.

It is not necessary to discuss the relative merits of gunpowder and high explosives. The experiments in Great Britain and on the Continent have so fully established the danger attending the use of the former in dusty and fiery mines that it is assumed that mining-engineers are agreed as to the advisability of restricting its use, and consequently the following remarks only apply to high explosives fired by detonation.

With respect to early experiments on the relative safety of low and high explosives, the Prussian Commission concluded that all low explosives were dangerous and all high explosives safe. Later experiments in Germany, and especially the results of the French Commission on the use of explosives in mines,* showed these conclusions regarding high explosives to be erroneous.

The work of the French Commission is of the highest importance, as it was a serious attempt to establish on scientific principles an enquiry into the conditions which determine the safety of explosives. The results have been so often quoted that they are wellknown, still they are so important that it is necessary to refer to them here. The method of experimenting permitted the comparison of the heat developed by the detonation of an explosive with that required by theory, and by using such simple explosives as nitro-glycerine, dynamite, blasting-gelatine, gun-cotton, and various mixtures of these with certain nitrates and other substances, the fact was established that provided complete detonation took place the heat actually developed corresponded with that calculated by theory. It was, therefore, possible to calculate the maximum temperature produced by the detonation of an explosive whose chemical constituents were known, on the assumption that the gases were generated under constant volume, and that the specific heat of the gases increased with the temperature according to certain laws established by Messrs. E. Mallard and Le Chatelier.

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* *Report of the French Commission on the Use of Explosives in the Presence of Fire-damp in Mines*, translated by Messrs. W. J. Bird and M. Walton Brown, and published by the North of England Institute of Mining and Mechanical Engineers.

This led to the result that the temperature of ignition of fire-damp under the influence of an explosive fired by detonation was apparently much higher than 750° Cent. (1,382° Fahr.), which is approximately the temperature of ignition in air under the influence of a steady flame. It was found that 50 grammes (1·76 ounces) of dynamite, whose temperature of detonation is 2,940° Cent. (5,324° Fahr.) would ignite fire-damp when fired freely suspended in an atmosphere containing 10·3 per cent. of that gas, but the same weight enclosed in a metallic tube 0·41 inch thick would not. In this case, the temperature of the gases was reduced to 2,150° Cent. (3 902° Fahr.) owing to the energy absorbed in fracturing the tube. Ignition, however, took place if the enclosing tube was 0·2 inch thick when the temperature of the gases was 2,280° Cent. (4,136° Fahr.), and it was concluded that the apparent temperature of ignition of fire-damp under the influence of a detonated explosive was between these two temperatures, namely, about 2,200° Cent. (3,992° Fahr.), and this result has been generally accepted as correct It was therefore concluded by the French Commission that the temperature of detonation was the condition controlling the safety of an explosive, and that this temperature should be below 2,200° Cent. (3,992° Fahr.). This opinion led to mixing of explosives with substances which would reduce the temperature of detonation, and of the substances used ammonium nitrate, originally proposed by Dr. Sprengel some years before, was found most suitable. Experiments, however, with mixtures of ammonium nitrate with dynamite and with gun-cotton led the French Commission to the conclusion that it was not sufficient for the temperature of

TABLE I.

Explosive.	Ammonium Nitrate.	Temperature of Detonation.	Weight of Charge.	Fire-damp in Atmosphere.	No. of Shots Fired.	No. of Ignitions.
	Per Cent.	Cent. Degs.	Ounces.	Per Cent.		
Dynamite (75 per cent.) ..	0	2,940	1·76	7·0	2	2
			1·76	8·7	3	3
			1·76	10·3	4	4
Dynamite (75 per cent.)...	50	2,000	1·76	10·3	4	2
Dynamite (75 per cent.)...	80	1,500	1·76	10·3	2	0
			3·53	10·3	4	0
			7·06	10·3	4	0
Gun-cotton (octonitric)...	0	2,064	1·00	6·1	1	1
			1·00	7·0	1	1
			1·00	8·7	3	3
			0·98	9·6	2	2
			1·00	10·3	1	1
Gun-cotton	80	1,930	1·76	10·3	8	0
			3·53	10·3	7	1
			7·06	10 3	2	2
Dinitro-benzene	85	2,120	1·76	10·3	8	0
			3·53	10·3	2	1

detonation to be simply below 2,200° Cent. (3,992° Fahr.) and that safety could not be ensured until the temperature fell to 1,500° Cent. (2,732° Fahr.), or at least to 1,900° Cent. (3,452° Fahr.).

It is impossible to quote largely from the numerous experiments made by the French Commission, but Table I. will serve to explain the character of the results.

Similar results were obtained with other mixtures, but these serve to show that apparently the safety increases as the temperature of detonation falls.

So satisfied were the French authorities with the main results that they framed their legislation regarding the use of explosives in mines upon them, and it was decreed that in gaseous or dusty mines all explosives were forbidden, other than detonating explosives, complying with the following conditions :—

1. The products of their detonation should not contain any combustible matter, such as hydrogen, carbon monoxide, solid carbon, etc.

2. Their temperature of detonation [calculated according to specified rules] . . . . . should not exceed 1,900° Cent. for explosives used in stone-work, nor 1,500° Cent. for those employed in coal-getting.*

The theory that the temperature of detonation is the controlling influence in determining the safety of explosives is a fascinating one, and *a priori* there is much to be said in its favour. There is no doubt that combustible mixtures cannot be ignited till their temperature of ignition is reached, and it is natural to suppose that the temperature of the gases escaping from the shot-hole should largely determine this ignition.

A perusal of the results of the experiments obtained by the French Commission show that they are generally in agreement with this theory ; but it must be remembered that the explosives used were comparatively simple ones, and composed for the most part of bodies whose heats of formation and modes of decomposition are wellknown. But it seems to the writer doubtful whether the temperatures calculated on theoretical considerations for the complex mixtures that to-day are used in the manufactures of explosives can possibly be accurate. Wood-meal, rye-flour, resin, and similar substances largely enter into their composition ; the heats of formation of these bodies are not accurately known, and even if they were, the chemical equations which are supposed to represent the decompositions from which the temperatures of detonation are calculated are so complicated that grave doubts must exist as to the accuracy of the numbers.

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* *Report of the French Commission on the Use of Explosives in the Presence of Fire-damp in Mines*, translated by Messrs. W. J. Bird and M. Walton Brown, and published by the North of England Institute of Mining and Mechanical Engineers, page 162.

The temperatures of detonation of a certain number of explosives is given in Table II.

TABLE II.—CALCULATED TEMPERATURES OF DETONATION.

	Temperature.	
	Degs. Cent.	Degs. Fahr.
Nitro-glycerine	3,150	5,702
Blasting-gelatine	3,090	5,594
Gelatine-dynamite (gelignite)	2,984	5,403
Dynamite (75 per cent.)	2,940	5,324
Bellite No. 1	2,124	3,855
Dahmenite A.	2,064	3,747
Wetter-dynamite	1,970	3,578
Coal-carbonite I.	1,868	3,394
Carbonite	1,845	3,353
Coal-carbonite II.	1,821	3,310
Westphalite	1,806	3,283
Cologne Rottweiller safety-explosive	1,774	3,225
Bellite No. 3	1,689	3,072
Roburite I.	1,616	2,941
Ammonium nitrate	1,130	2,066

But apart from the uncertainty which attaches to these temperatures for the explosives of more complicated composition, results obtained in Germany seem to show that the temperature of detonation is not the sole condition that controls the safety of the explosive. If this were so, then the weight of the explosive fired would have no influence in bringing about ignition, for the temperature of detonation is constant for all weights, and provided it were sufficiently low, 1 ounce or 20 ounces should be equally safe. Mr. Lohmann* found that the early conclusions of the Prussian Commission regarding the safety of high explosives were not so certain if the weight of explosive used was increased, and subsequently he proved that 100 grammes (3·53 ounces) of dynamite and gelatine-dynamite would invariably ignite dust and gas.

Later, Mr. Winkhaus,† as the result of his experiments at Schalke, proved that for each explosive there is a maximum weight that can be used with safety, which cannot be exceeded without greatly increasing the danger of igniting explosive mixtures. The weight decreases as the percentage of gas increases. Table III. shows the minimum weight of explosives which, under the conditions of experiment in the testing-station at Schalke, would produce ignition of various mixtures of gas and dust.

Since the publication of these results, Mr. Heise has continued the investigation under slightly different conditions, and has completely

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* *Zeitschrift fur das Berg- Hütten- und Salinenwesen*, vol. xxxv., pages 271 and 352.

† *Trans. Inst. M.E.*, vol. ix., page 250; and *Glückauf*, 1894, page 1651, and 1895, pages 559, 577, and 597.

TABLE III.—MINIMUM WEIGHT OF EXPLOSIVE IN OUNCES PRODUCING IGNITION (MR. WINKHAUS).

Explosive.	Pit-gas.				Dust.	
	2¼ Per Cent.	6 to 7 Per Cent.	8 Per Cent.	9 Per Cent.	Alone.	+ 6 to 7 Per Cent. of Gas.
	Ounces.	Ounces.	Ounces.	Ounces.	Ounces.	Ounces.
Blasting-gelatine ...	2·65	1·76	1·33	0·35	5·3	1·58
Dynamite	2·65	2·05	—	—	—	1·06
*Stonite	3·92	2·86	—	—	—	—
†Roburite	5·36	2·40	—	—	—	4·59
‡Roburite No. 1 ...	—	—	14·12	8·82	21·88 N	21·88
§Wetter-dynamite ...	7·05	5·43	—	—	—	1·08
‖Westphalite	10·58	8·85	—	—	—	8·82
¶New westphalite ...	—	—	17·65	5·30	21·18	21·18 N
**Dahmenite	12·35	8·85	—	—	—	8·82
††Dahmenite A ...	—	—	14·12	3·53	19·4	17·65
‡‡Progressite	14·11	19·4	—	—	—	19·76
§§Carbonite	15·88 N	21·17 N	21·18 N	21·18 N	35·3 N	29·64 N

N = Non-ignition, the experiments not being continued beyond these weights.

* Nitro glycerine, 68; kieselguhr, 17; potassium nitrate, 10·5; rye-meal, 3·5; and soot, 1.

† Dinitro-benzene, 17·8; ammonium nitrate, 79·2; ammonium chloride and sulphate, 0·3; and moisture, 2·7.

‡ Dinitro-benzene, 7·4; ammonium nitrate, 88·2; and manganese dioxide and potassium permanganate, 4·4.

§ Nitro-glycerine, 52·9; magnesium sulphate, 32·7; and kieselguhr, 14·4.

‖ Ammonium nitrate, 94; resin, 5·4; ammonium chloride, 0·1; and ammonium sulphate, 0·4.

¶ Ammonium nitrate, 89·6; resin, 5; and potassium bichromate, 4·9.

** Naphthalene, 4·8; ammonium nitrate, 93·3; potassium chlorate, 1·6; ammonium chloride, 0·1; and ammonium sulphate, 0·2.

†† Naphthalene, 4·5; ammonium nitrate, 92·9; and potassium bichromate, 2·6.

‡‡ Aniline hydrochloride, 4·7; ammonium nitrate, 89·1; and ammonium sulphate, 6.

§§ Nitro-glycerine, 25; potassium nitrate, 34; rye-meal, 38·5; wood-meal, 1; barium nitrate, 1; and sodium carbonate, 0·5.

confirmed Mr. Winkhaus's conclusions. In Table IV. is given the minimum weights of explosive producing ignition, at least once in five consecutive shots, of various mixtures of dust and gas.

The explosives were tested in weights gradually increasing by 50 grammes (1·76 ounces), and the weights given are 1·76 ounces heavier than the weight which did not ignite the mixture in five consecutive shots.

The fact that there is a certain weight that determines ignition is a very serious objection to the theory of the French Commission. In Table V. is made a comparison between the calculated temperatures of detonation and the minimum weight producing ignition of dust with 8 per cent. of pit-gas.

There does appear to be an increase in the limiting-charge of safety with decrease in the temperature of detonation in the case of the nitro-glycerine explosives, but amongst the ammonium-nitrate explosives this is by no means so. Dahmenite A, whose temperature of detonation is apparently the highest (2,064° Cent. or 3,747° Fahr.), shows the least

TABLE IV.—MINIMUM WEIGHT OF EXPLOSIVES IN OUNCES PRODUCING IGNITION (MR. HEISE).

Explosive.	Dust.				
	Alone.	+ 2½ Per Cent. of Pit-gas.	+ 6·5 Per Cent. of Pit.gas.	+ 8 Per Cent. of Pit-gas.	+ 9 Per Cent. of Pit-gas.
[*]Gelatine-dynamite	2·12	1·09	—	0·28	—
[†]Carbonite	28·24N	28·24N	—	31·77N	31·77N
[‡]Carbonite No. I.	—	—	—	25·6N	—
[§]Carbonite No. II. ...	—	—	—	25·94N	—
[‖]Cologne-Rottweiler safety-explosive	21·18N	21·18	17·65	8·82	—
[¶]Roburite	14·12	12·35N	12·35N	12·35	—
[**]Roburite	17·65	19·41	17·65	—	—
[††]Dahmenite A	21·18N	21·18	17·65	17·65	—
[‡‡]Victoria powder	—	—	—	24·71N	—
[§§]Westphalite	21·18	21·18N	17·65	12·35	—

N = Non-ignition, the experiments not being continued beyond these weights

[*] Nitro-glycerine, 62·5; nitro-cotton, 2·5; sodium nitrate, 25·5; wood-meal, 8·75; and sodium carbonate, 0·75.

[†] Nitro-glycerine, 25; potassium nitrate, 34; wheat-meal, 38·5; tan, 1; barium nitrate, 1; and sodium carbonate, 0·5.

[‡] Nitro-glycerine, 23; sodium nitrate 30·5; meal, 37; potassium bichromate, 5; and water, 2·5.

[§] Nitro-glycerine, 30; sodium carbonate, 24·5; meal, 38; potassium bichromate, 5; and water, 2·5.

Ammonium nitrate, 92·5; sulphuretted oil, 6·3; barium nitrate, 0·8; and moisture, 0·4.

[¶] Dinitro-benzene, 7·1; ammonium nitrate, 88·3; potassium permanganate, 4·1; and moisture 0·5.

[**] Dinitro-benzene, 7; ammonium nitrate, 87·5; ammonium sulphate, 5; and potassium permanganate, 0·5.

[††] Naphthalene, 6·48; ammonium nitrate, 91·3; and potassium bichromate, 2·22.

[‡‡] Granulated dahmenite A.

[§§] Ammonium nitrate, 91; potassium nitrate, 4; and resin, 5.

TABLE V.

Nitro-glycerine Explosives.	Temperature of Detonation.		Minimum Weight producing Ignition.	Ammonium Nitrate Explosives.	Temperature of Detonation.		Minimum Weight producing Ignition.
	Degs. Cent.	Degs. Fahr.	Ounces.		Degs. Cent.	Degs. Fahr.	Ounces.
Gelatine-dynamite	2,984	5,403	0·28	Dahmenite A ...	2,064	3,747	17·65
Dynamite (75 per cent.)	2,940	5,324	0·24	„ granulated	2,064	3,747	24·65N
Carbonite I. ...	1.868	3,394	25·6 N	Westphalite ...	1,806	3,283	12·35
Carbonite ...	1,845	3,353	31·77 N	Cologne-Rottweiler	1,774	3,225	8·82
Carbonite II. ...	1,821	3,310	25·94 N	Roburite... ...	1,616	2,941	12·35

N = Non-ignition, the experiments not being continued beyond these weights.

tendency to ignite the explosive mixture, while westphalite is equally as safe as roburite, notwithstanding that its temperature of detonation is 190° Cent. (342° Fahr.) higher, and Cologne-Rottweiler safety-powder is apparently the least safe.

It is interesting to note the effect of granulation on the safety of dahmenite A, which had raised the limiting charge from 17·65 ounces with ignition to 24·65 ounces without ignition. This will be discussed later, and for the present it suffices to point out that, although the same temperature of detonation is given to both explosives, it is by no means proved that it is correct to do so. Whether it is the same or not will depend on the course of the chemical decomposition, and only if this is the same in both explosives will identical numbers represent the temperatures of detonation. It is also important to note that in France the three carbonites and all the ammonium-nitrate explosives given in Table V. would be forbidden for use in coal, whilst dahmenite A would be absolutely forbidden in coal-mines, notwithstanding that it apparently possesses a high degree of safety.

But this theory must not be condemned too hastily, for Mr. Winkhaus* has shown that the safety of any explosive is increased by so altering its composition that its temperature of detonation is reduced. For instance, by taking various mixtures of dinitro-benzene and ammonium nitrate (bellite) the results shown in Table VI. were obtained.

TABLE VI.

Temperature of Detonation.		Composition.		Weight Igniting.	
		Ammonium Nitrate.	Dinitro-benzene.	Dust.	Dust and 7 Per Cent. of Pit-gas.
Degs. Cent.	Degs. Fahr.	Per Cent.	Per Cent.	Ounces.	Ounces.
2,200	3,992	83	17	7·93	1·76
2,047	3,717	86	14	10·58	3·53
1,870	3,398	89	11	17·64	5·29
1,696	3,085	92	8	17·64 N	12·35
1,482	2,700	95¼	4¾	17·64 N	17·64

The introduction into roburite of 4 per cent. of potassium permanganate (Table III.) has raised the limiting-charge igniting dust with 7 per cent. of pit-gas from 4·59 to 21·88 ounces, while the effect of replacing 1·6 per cent. of potassium chlorate in dahmenite by 2·6 per cent. of potassium bichromate is to raise the weight from 8·82 to 17·65 ounces. The action of substances such as potassium bichromate and potassium permanganate is doubtless to absorb some of the heat generated by the explosion, and so reduce the temperature of detonation: but at the same these alterations in composition affect the blasting efficiency of the explosives themselves, and one must enquire how this affects the safety.

The Austrian Commission concluded from its experiments that the safety of an explosive is in the inverse ratio to the force it exerts. This is contrary to the opinion that was held by the Prussian Commission, that the quicker an explosive the safer it is. Quite recently, Mr. Heise[*] has obtained results which seem to confirm the conclusions of the Austrian Commission, and on them bases a theory that the safety of an explosive depends on its shattering power. The shattering power depends on the pressure developed in the shot-hole and on the time occupied by the decomposition: it increases as the pressure increases and the time decreases. Hence, for the same pressure developed the greater shattering power is possessed by the quicker explosive. Mr. Heise's theory is that the safety varies inversely as the shattering power, or the slower the explosive the safer it is.

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* *Trans. Inst. M.E.*, vol. x., page 337.

Attention has been drawn to the marked increase in the safety of dahmenite A (Table IV.) by granulation, and the same effect is produced by granulating roburite, for whereas 12·35 ounces of ordinary roburite ignited dust with 7 per cent. of pit-gas (Table IV.), 21·18 ounces of the same explosive, specially granulated, failed to do so. This improvement, Mr. Heise states, is due to a reduction in the shattering power, which he believes he can determine by a modification of the usual Trauzl method for determining the strength in leaden blocks.

Instead of firing fixed weights of 10 grammes, he takes weights of explosives corresponding to 2,500 kilogrammetres of work, as calculated from the theoretical amount of energy which the explosive is capable of exerting, and in place of confining the charge closely in the leaden blocks, so that the total energy can be spent in enlarging the cavity, he simply covers the charge with 50 cubic centimetres of dry sand, and

TABLE VII.

Explosive.	Strength determined with 10 Grammes Explosive, Carbonite being 100.	Weight equal to 2,500 Kilogrammetres of Work.		Shattering Power corresponding to these Weights, Carbonite being 100.	Limiting-charge of Safety in Dusty Atmosphere containing 8 Per Cent. of Pit-gas.
		Grammes.	Ounces.		Ounces.
Carbonite	100·0	10·82	0·382	100·0	31·77 N
Carbonite I.	112·2	10·46	0·369	105·5	25·60 N
Carbonite II.	119·4	10·78	0·380	121·8	25·90 N
Cologne-Rottweiler ...	166·0	9·40	0·331	143·0	8·82
Dahmenite A	230·0	7·33	0·258	137·3	17·65
,, granulated	164·1	7·33	0·258	109·0	24·71 N
Roburite I.	155·8	11·36	0·401	157·9	12·35
Westphalite	188·8	9·12	0·321	157·9	12·35

N signifies non-ignition, and that the explosive was not tested beyond this weight.

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[*] *Glückauf*, 1898, pages 657, 684, 709, and 721.

the enlargement thus obtained he believes is a measure of the shattering power. In Table VII. are given (1) the strength as determined by using 10 grammes of each explosive; (2) the shattering power as determined by Mr. Heise's modified method (in both cases the strength of carbonite is taken as 100); and (3) the limiting-charge of safety as determined by Mr. Heise for dust with 8 per cent. of pit-gas.

There is a remarkable agreement between the numbers in the two last columns of Table VII. The increase in shattering power is followed by the same order in the decrease of safety, with one exception. The explanation of the connexion between the shattering power and safety offered by Mr. Heise is as follows:—The sudden development of pressure causing the shattering effect produces a wave of compression in the surrounding atmosphere, under which the gases become heated; and the greater the compression the higher the temperature of the atmosphere is raised. The compression will be greater the more sudden the development of the pressure; that is, the more rapid the decomposition or the greater the shattering power. And Mr. Heise points out that under the enormous pressure produced by the detonation of explosives, it is possible to conceive that the temperature of the atmosphere in the compression-wave may be raised to the ignition-temperature of the explosive mixture in the air, and hence the firing of the gases may take place independently of the temperature of detonation.

It is not the writer's intention to enter into a lengthy criticism of this theory, which has already been undertaken by Messrs. Watteyne and Denoël.* But it must be pointed out that if the theory be correct the safety of any one explosive should decrease with the "density of charge," that is the weight of explosive in grammes divided by the volume in cubic centimetres that it occupies; for the pressure developed does not vary with the weight of the charge, but with its density, hence, as the density increases the safety should decrease. But if the compression is not sufficient to ignite the gases, ignition will occur if the retardation of the ignition of fire-damp is less than the interval required for cooling the gases as they shoot out of the shot-hole. This interval will be longer as the temperature of the escaping gases is higher. The temperature of the gases when they come into contact with the explosive mixture is not equal to the temperature of detonation, because (even assuming that the latter is developed at the moment of decomposition) cooling takes place owing to the energy consumed in doing mechanical work and the heat absorbed in raising the temperature of the surrounding rocks. The amount of the latter cooling effect is determined by the time the gases remain in contact with the rocks, and this is shorter the greater the velocity imparted to the escaping gases. This velocity is determined by the initial pressure of the gases, which also determines the shattering power. Now, assuming that two explosives have the same temperature of detonation and do the same amount of mechanical work, then the shattering power determines the temperature of the escaping gases. But in the case of two explosives having the same shattering power and doing the same amount of work, then the temperature of detonation will determine the temperature of the gases, so that it appears probable that both temperature of detonation and velocity of decomposition or shattering power exert an influence on the safety of an explosive.

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* *Annales des Mines de Belgique*, vol. iii., page 801.

There is another property of explosives to which the Austrian Commission pay some attention, namely, the flame produced on detonation. In the experiments carried out for the Royal Commission on Accidents in Mines, and in the experiments of the Chesterfield and Midland Counties Institution of Engineers, observations were made on the length of flame produced by firing charges of gunpowder, with the result that considerable elongation in the flame was caused by the presence of gas and dust; and the same conclusions have been arrived at from the *Report of the Proceedings of the Explosives Committee of the North of England Institute of Mining and Mechanical Engineers*, on the flames of high explosives. A summary of their results is presented in Table VIII.

TABLE VIII.

Explosive.	Weight Fired.	Length of Flame.				
		Air.	4 Per Cent. of Coal-gas.	6 Per Cent. of Coal-gas.	8 Per Cent. of Coal-gas.	10 Per Cent. of Coal-gas.
	Ounces.	Feet.	Feet.	Feet.	Feet.	Feet.
Bellite	1	16 to 19	19	28 to 45	I*	—
Ammonite	1⅛	28 to 36	28 to 45	45 to 62	I	—
Roburite	1¼	16 to 18	28 to 36	45	I	—
Carbonite	2½	19 to 28	10 to 36	28	I	I
Ardeer powder ..	3¾	16 to 19	19 to 36	10 to 36	I	I
Westphalite... ...	1½	13 to 27	—	—	{9 % gas 5}	—

* I = Ignition in one or more of the experiments, but not necessarily in all.

The results shown in Table VIII. were obtained by direct observation, and it is difficult to realize that such small weights of explosives could produce flames varying in length from 13 to 36 feet when fired into air. Mr. A. Siersch, however, has applied photography to obtaining impressions of the flashes produced when freely-hanging cartridges and shots blown out from a cannon are fired. His results have been presented to the members,[*] and an examination of the reproductions of his photographs shows that explosives like dynamite, blasting-gelatine, gelatine-dynamite, and gun-cotton, which have been universally condemned as dangerous, give large spreading flames, whilst the safer explosives roburite, carbonite, westphalite, progressite, etc., give smaller and less spreading flames. Now, it seems reasonable to suppose that the larger the flame the longer it will last, and the larger the amount of gas or dust with which it will come into contact, and hence the greater the ease with which ignition will be brought about. It is, therefore, possible to conceive that a large flame of low temperature lasting for a long time may produce ignition, whereas a small and considerably hotter flame lasting for a comparatively short time may not: for the ignition of the gas depends on the interval occupied in the cooling of the gases as they issue from the shot-hole and the retardation of the ignition of fire-damp. Now, Mr. Siersch shows that the size of flame increases with the weight of charge, and hence it may be that for each explosive there is a definite weight, the flame of which lasts sufficiently long to exceed the interval of retardation. But what the size of flame must be and the time that it must last seems to the writer to depend on its temperature and the velocity of the gases as they escape from the shot-hole. The higher the temperature the shorter the time that it needs to exist, and the greater the velocity of the gases, the less the cooling which they suffer by contact with the solid material that is being blasted; and consequently the higher their temperature when they meet the explosive mixture, and also the greater the distance the flames will be projected into the explosive mixture.

Now, the flames represented in the experiments are similar to what may be expected to result from blown-out shots, and not to what obtains in actual working when the shot does proper execution. In such cases, it seems possible that the size of the flame and the velocity of the gases will be of equal importance, for with explosives giving small flames probably all flame has ceased to exist before the gases meet with the surrounding atmosphere; but with explosives giving large flames, or in which high velocity is communicated to the gases of decomposition, it is possible that some flame will escape into the atmosphere.

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[*] *Trans. Inst. M.E.*, vol. xi., page 2.

From this discussion it will be gathered how complex is the question of the conditions determining the safety of explosives. So far it appears that there are at least three—the temperature of detonation, shattering power, and flame—and there may be others. The French Commission is satisfied that the temperature of detonation controls the safety, whilst the Prussian authorities are prepared to reject this conclusion, and rely on the shattering power ; and the Austrian Commission alone takes into consideration all three conditions.

It has already been stated that the object of reviewing the results of investigations on the safety of high explosives is to form a basis for the discussion of methods for testing, and as again on this branch of the subject authorities widely differ, it will be advisable to refer briefly to the most important of the methods that have been or are being used.

METHODS OF TESTING.

(*a*) *France.*—In France, the theoretical aspect of the question was made the basis of research, and the *Report of the French Commission on the Use of Explosives in the presence of Fire-damp in Mines* is one of the most valuable contributions on the subject. The apparatus consisted of a closed steel boiler of about 350 cubic feet capacity, in which explosives could be fired in air alone, or in atmospheres containing known percentages of marsh gas or coal gas up to 10·3 per cent. The boiler was fitted with a pressure-gauge for registering the pressure at definite intervals after the shot was fired, so that the pressure at the moment of explosion could be deduced, and from it the heat evolved by the decomposition calculated. The cartridges, generally weighing 50 grammes (1·76 ounces), were at first suspended in the centre of the boiler, but it was determined that, unless the explosive was easily susceptible to detonation, incomplete detonation took place under these conditions, and subsequently the cartridges were enclosed in metallic tubes of known thickness. As a supply of pit gas could not be obtained, recourse was had to artificially prepared methane. It will be seen that no attempt was made to imitate working conditions, but many of the results obtained have had important influence on the technology of explosives, especially the conclusions arrived at regarding the value of ammonium nitrate as a constituent of safety-explosives, and although the main conclusions regarding the safety of explosives may not have been confirmed by subsequent experiments, such a result as the above is sufficient to establish the value of the French researches.

(*b*) *Prussia.*—The method adopted in Prussia imitates more closely the conditions of actual working. Galleries are built of oval section to resemble the roadway of a mine; at one end is a substantial block of masonry, in which is embedded a cannon, whilst the other end remains open. The galleries are fitted with safety-valves for the relief of the pressure produced by the explosions, and sight-holes for observation of the results. The cannon has a bore-hole along its axis to represent the shot-hole in blasting, and the cannon and bore-hole are of such a size that gradually increasing weights can be fired, in some cases the weights used amount to 35 ounces.

At present there are two such galleries in Germany, one at the König colliery, Neunkirchen, near Saarbrücken, which is under the control of Government mining-officials, the other at the Braubauer shaft of the Consolidation colliery, near Gelsenkirchen, belonging to the Westphalian Miners' Provident Association.

The former gallery is 25 metres (82·02 feet) long, and is made of elliptical iron rings, to which a timber lining is fastened; the major axis, which is vertical, measures 1·72 metres (5·64 feet), and the minor axis 1·2 metres (3·93 feet). The sight-holes are on one side at a height of 1·2 metres (3·93 feet) from the bottom of the gallery. The cannon is a cylinder 750 millimetres (29·53 inches) long, and 495 millimetres (19·49 inches) in diameter; it is composed of a core of forged steel, 165 millimetres (6·50 inches) in diameter, on which is shrunk a steel mantle, 165 millimetres (6·50 inches) thick. The bore-hole is 450 millimetres (17·72 inches) deep and 55 millimetres (2·16 inches) in diameter. The cannon is inclined, so that its axis meets the horizontal axis of the gallery at a distance of 5 metres (16·40 feet) from the face of the masonry. A chamber for the reception of explosive mixtures is made by fixing a paper-diaphragm at such a distance from the masonry block that it encloses a capacity of 10 cubic metres (353 cubic feet). The gallery is almost completely buried on one side, by being built into the side of a pit-heap, whilst the other side is built up with soil for about one-half its height. The gas used is obtained from a blower in the König colliery, and the dust is that obtained from the colliery-screens.

The Westphalian gallery is similar to that just described, and a full description of it is given in Mr. Winkhaus's paper on Safety-Explosives.* It is only necessary, therefore, to point out in what respects it differs from the gallery at Neunkirchen. In the first place, it is of larger dimensions; its length is 35 metres (115 feet), its height

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* *Trans. Inst. M.E.*, vol. xi., page 250.

1·85 metres (6·07 feet), and its greatest width 1·35 metres (4·43 feet). The cannon is inclined, so that its axis cuts the roof of the gallery at a distance of 10 metres (32·81 feet) from the face of the masonry. The paper-diaphragm for enclosing the explosion-chamber is fixed at a distance of 5·1 metres (16·73 feet) from the masonry, and the space thus enclosed is 10 cubic metres (353 cubic feet).

Since Mr. Winkhaus described the gallery, it has been removed from its original site at Schalke to the Braubauer shaft, Gelsenkirchen: advantage has been taken of this removal to bury the gallery almost completely below the surface, and now only the safety-valves and the sight-holes are left exposed. A sort of fan or agitator is fixed within the explosion-chamber, for the purpose of agitating the dust and ensuring the uniform mixing of the gas and air. The gas used is obtained from a blower in the adjoining pit, and the dust is obtained by grinding the coal and sieving it through gauze having 1,200 apertures per square centimetre.

(*c*) *Austria.*—The experiments are carried out at two stations, one at Mährisch-Ostrau and the other at Segengottes. These galleries are similar in shape and size to those constructed in Germany; they are about 164½ feet long, and the shots are fired in explosion-chambers built of masonry at one end of the gallery.

At Segengottes, the chamber is of 106 cubic feet capacity, and that at Mährisch-Ostrau measures 644 cubic feet. A permanent committee has been appointed at each station to carry out experiments, and the general plan is to fire unconfined cartridges, either freely suspended in the chamber or laid on the floor; in the latter case they may be covered with tamping or coal-dust.

(*d*) *Great Britain.*—In this country, the experiments recently carried out are on a much smaller scale, and no attempt is made to imitate the conditions of actual working. The experiments by Mr. M. Walton Brown,* as well as those reported on by Messrs. A. A. Atkinson, M. Hall, and E. W. Thirkell,† were on a more or less practical scale. In both cases shots were fired from mortars into cylindrical boilers which were comparatively short. The tests, however, did not deal with the safety of the explosives generally. The most important experiments in this respect were those carried out by The North of England Institute of Mining Engineers on so-called "flameless explosives." The methods of testing and the apparatus used are so wellknown that a lengthy description is unnecessary. The gallery is circular, 3 feet in diameter and 101 feet long; in it a paper-partition can be fixed to enclose an explosion-chamber of a capacity of 159 cubic feet. The cannon is movable, being mounted on a trolley, so that it can be run against the closed end of the gallery when charged for firing; it consists of a cylindrical steel block, 4½ feet long, 18 inches in diameter at the breech for a length of 18½ inches, and 15 inches in diameter for the remainder of its length. The bore-hole drilled along the axis is 42½ inches long and 1⅛ inches in diameter. The cannon is inclined, so that its axis would meet the lower side of the gallery at a distance of 38 feet from the firing-end. The method of testing consisted in firing fixed and small weights of various explosives into different mixtures of air with pit-gas and coal-gas, with and without dust. The weights used were in the inverse ratio of the strengths of the explosives as determined by the Trauzl method, and varied from 1 ounce of bellite to 3¾ ounces of ardeer powder. The pit-gas used was obtained from a blower at Hebburn colliery.

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* *Trans. Inst. M.E.*, vol. ii., page 49.

† *Ibid.*, vol. xi., page 294.

In 1896, the Home Secretary determined to take up the subject of testing explosives, and erected a gallery at Woolwich, practically on the same lines as that at Hebburn, but on a still smaller scale. It is fully described in the *Transactions*,[*] but no dimensions have been published. It would appear, however, from the official drawings, to be about 2¼ feet in diameter and about 25 feet long. The whole gallery has a capacity of about 99½ cubic feet, and this constitutes the explosion-chamber. No experiments are carried out with dust in the gallery, but a special chamber is used for this purpose. It consists of a cylinder about 8 or 9 feet long and about 4 feet in diameter, placed in a vertical position; into this dust is blown by means of a fan, and shots are fired from a cannon buried in the ground with its axis vertical. The system of firing fixed weights of explosives is adopted, and the test is described as follows, in the Order of Council dated October 8th, 1897:—

> The test will be carried out for each explosive with the size of detonator recommended by the manufacturer or person submitting the explosive, and every shot shall be fired electrically. All charges to be stemmed with 9 inches of dry clay well rammed. Each shot to be fired into a highly explosive mixture of coal-gas and air, the gas being supplied from the Royal Arsenal Gas-works.[†]
>
> The charges of explosives to be fired will be determined as follows:—
>
> (*a*) In the case of the explosives intended to be fired by a detonator, and commonly called high explosives, the charge will be taken as the equivalent of 2

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[*] Vol. xiii., page 612.

[†] The mixture of gas and air used contains about 9 per cent. of gas, which was found by experiment to be the most sensitive to ignition.

ounces of dynamite No. 1, containing 75 per cent. of nitro-glycerine, as determined by the enlargement obtained on firing the same in a leaden cylinder tamped with loose sand.

(b) In the case of gunpowder, or any explosive not intended to be fired with a detonator, the charge will be taken as equivalent to 6 ounces of R.F.G.[2] powder, as determined by the enlargement obtained on firing the same in a leaden cylinder tamped with loose sand and heavily weighed above with a mass of metal.

Each explosive shall be subjected to the following test:—A number of shots shall be tried, not exceeding 40. If in the first 20 no failure occurs, or in the first 30 only one failure, or in 40 only two failures, it will be passed. A shot shall be regarded as a failure (1) if it ignites the gaseous mixture, (2) if it leaves an appreciable amount of charge unexploded.

Such are the various methods that have been or are at present adopted in testing explosives, and, in discussing their relative merits, it is necessary to come to some conclusion as to what standard should be adopted as a measure of safety. The standard may be either theoretical or practical.

From the theoretical point of view, the safety of an explosive depends on the interval of time that elapses between the retardation of the ignition of fire-damp and the cooling of the highly-heated gases as they escape from the shot-hole. It has already been shown that this is apparently dependent on the temperature of detonation, the shattering power, and the amount of flame ; but the interdependence of these conditions is so complex and so little understood that methods based on theoretical considerations alone can hardly be relied on at present to give satisfactory results. The French tests were based on such theoretical considerations. The results, from which the main conclusions were drawn, have not been confirmed by subsequent experiments, and the restriction of the temperature of detonation to 1,500° Cent. (2,732° Fahr.) for work in coal prevents the use of such valuable explosives as carbonite, roburite, westphalite, and others, except in stone-work. From the practical point of view, the most rational standard is the maximum weight that can be used without igniting the most explosive mixtures of dust and gas. This method is empirical, but it has the advantage of showing the relative safety of the various explosives under the conditions of testing, and therefore affords mining engineers some guidance in making their selection.

In the Westphalian testing-station such a standard is actually set up. Gradually increasing weights of each explosive are fired from the cannon into various mixtures of gas and dust, and the latest standard, adopted by Mr. Heise as the limiting-charge of safety, is the maximum weight of which five consecutive shots can be fired into a dusty atmosphere containing 8 per cent. of pit-gas without producing ignition. This test may seem unnecessarily severe, seeing that the shots are fired unstemmed; but the beneficial results accruing from it are seen in the high degree of safety that has been reached by the explosives in use in Westphalia, as shown in Table IV.

At Neunkirchen, a more artificial standard is fixed. Up to 1896, according to Mr. Dröge,* an explosive was considered sufficiently safe if 250 grammes (8·82 ounces) fired from the mortar caused no explosion in presence of coal-dust or fire-damp mixtures containing 7 per cent. of marsh-gas. But H.M. Inspector of Explosives states that he has reason to believe that the standard is, that 500 grammes (17·64 ounces) fired into a 2½ per cent. mixture of pit-gas and air together with 2 litres of coal-dust must not produce ignition.†

In Austria, each station is under the control of a separate permanent committee, and last year these committees met in conference with the Austrian Technical Military Committee, and drew up regulations to establish an uniform system of testing. Amongst the conditions laid down the following are the most important:—Tests of strength and safety are to be carried out simultaneously. As a basis for a minimum degree of safety, 100 grammes (3·53 ounces), wrapped in parchment paper and exploded in the open, shall not ignite a 7 per cent. mixture of pit-gas and air for the Mährisch-Ostrau collieries, and a 10 per cent. mixture for the Segengottes collieries. Experimental determinations of the temperature of detonation shall be made. The temperature is not to exceed 1,500° Cent. (2,732° Fahr.). Photographs are to be taken of the flames produced. The effect of blown-out shots in igniting dusty and gaseous mixtures is to be tested with a fixed weight of 100 grammes (3·53 ounces) fired from a mortar.

In these tests the standard of safety fixed is somewhat low, but the first test is very severe, seeing that the explosive is not confined in a cannon. The general system of recording other properties beside the ability or inability to ignite explosive mixtures is worthy of being copied.

What the standard is in Great Britain, it is difficult to define, for by using small and constant weights it is impossible to distinguish between an explosive like carbonite, of which 31·77 ounces has failed in the Prussian experiments to ignite dust containing 8 per cent. of pit-gas, and roburite and westphalite which, under the same circumstances, produced ignition when 12·35 ounces were fired.

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* *Zeitschrift für das Berg- Hütten- und Salinen-Wesen*, vol. xlv., page 186.

† *Annual Report*, 1897, page 139.

The Woolwich test is doubtless a very severe one, but the writer has always expressed the opinion that it is not sufficient to guarantee the safety of the explosives tested, and lately Captain Thompson has stated that the "permitted list" only implies that such explosives are safer than one which has failed to pass the test. It will be seen, therefore, that while there is no standard in Great Britain for measuring the relative safety of explosives, standards of a more or less practical character are established on the Continent, and in the writer's opinion the practical standard is the best to adopt, for it at once offers a guide for selection. But what should the standard be? Should it be that adopted in Westphalia, where each explosive is tested on its own merits, or should a limit be placed on the charge to be fired? In the writer's opinion, the Westphalian standard is too severe, and although it thoroughly tests the relative merits of explosives, it is bound to restrict the use of permitted explosives within very narrow limits, and somewhat hamper the coal-industry. It seems more reasonable to fix a limit to the weight that shall not ignite gaseous mixtures; but that weight should be comparable with the charges generally employed in actual working. The weight adopted at Neunkirchen seems a reasonable one, while that in Austria seems small; but in that country the low temperature of detonation required will serve as a check against the permission to use unsafe explosives.

The object of criticizing the present methods of testing is to come to some conclusion as to what is a satisfactory method to adopt. The best is that which is based on a practical standard, but it should be possible not only to determine the relative safety according to the standard fixed, but also to make observations on all the properties which may influence the safety of an explosive. The object of testing explosives should be twofold: (1) to give mine-managers a guide to selection and (2) to arrive at some knowledge on the theoretical conditions that determine the safety. The first object is of primary importance for the present practical needs of the consumer; the second is of importance, as it will enable manufacturers to place at the disposal of the coal-industry explosives which, as far as possible, aim at fulfilling these conditions. The testing-method adopted for the first object should resemble the conditions of actual working as closely as possible. So far as the size of galleries used in Prussia and Austria is concerned, this point is to a certain degree met. Working conditions, however, would be more closely approached by the introduction of props and other obstructions in the line of fire; and if Mr. Heise's theory regarding the compression of the atmosphere is correct, the presence of obstructions should materially affect the ease with which the gases are ignited. Further, it has been shown in many instances that the effect of the ventilating-current is to elongate the flame produced on explosion, and in view of the influence which the flame may have on the ignition of gas it appears desirable to be able to test explosives in both still and moving atmospheres. It will be within the recollection of the members that a committee reported on a gallery complying with these conditions,* in which it would be possible to test explosives with or without obstructions in the line of fire, both in still and moving atmospheres.

There is one respect, however, in which experimental tests can never imitate blasting-operations, namely, in the fracture of the surrounding material. This makes the experimental method more severe, as the shot performs very little mechanical work, and the question to decide is whether the cartridge should be confined in a cannon, or hang freely and unconfined in the explosive mixture. The Prussians adopt the former method and the Austrians the latter. It is doubtful, however, whether the Austrian method is to be recommended, in view of the fact shown by the French Commission, that many explosives when unconfined are liable to incomplete detonation. Mr. Heise confirms this opinion, as he found by firing practically unconfined cartridges of dynamite and blasting-gelatine that the former was about twice as strong as the latter, which he attributes to the incomplete detonation of the blasting-gelatine. The writer has also found that when explosives containing dinitro-benzene are fired unconfined there is a strong odour of dinitrobenzene in the fumes, which may be attributed to incomplete decomposition. Cartridges confined in a cannon or in strong metallic tubes are capable of complete detonation, and were it not for the expense and the danger of destroying the gallery, the writer believes that firing shots in strong metallic tubes would be the best plan to adopt; but as this does not seem practicable, especially with heavy charges, recourse must be had to firing shots from a cannon, which should be strong enough and have a bore-hole large enough, to hold charges of from 25 to 30 ounces.

In a gallery of this description, it is believed that tests of such a practical character could be carried out that the results would appeal to the confidence of mining engineers, and greatly assist them in selecting explosives. Doubtless considerable information on the action of explosives under these working conditions would be obtained by this method alone; but to complete the objects already mentioned the Austrian method should be adopted, of carrying out simultaneously observations on the strength of the explosives, on the character of their flame, on their temperature of detonation as determined by actual experiment, and lastly, a careful analysis of each explosive should be made and its products of decomposition determined.

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* *Trans. Inst. M.E.*, vol. xiv., page 415.

By a careful co-ordination of the results obtained in carrying out a systematic series of tests of this description, it should be possible to arrive at some solution of that complex question, on what does the safety of an explosive depend?

It seems a pity, when the Home Secretary decided to build a testing-station, that he should have let the opportunity pass of erecting one at which the question of safety could be investigated in a practical and scientific manner. As it is, his action has practically put an end to individual investigations, whilst it leaves the position of explosives in very much the same condition as it was before the "permitted list" was established. He refuses to take the responsibility of determining the relative safety of explosives, for fear of hampering an important industry; but leaves the mine-manager the anxiety of selecting from a list of explosives whose safety he does not guarantee.

It may be said that the results obtained on the Continent may guide members, but this is a mistake. These results are only applicable to explosives which have the composition of those tested; and it must be borne in mind that explosives bearing the same name in different countries are not identical in composition; therefore, whilst we may come to some conclusions as to the conditions determining safety from these results, it is by no means sure that the British explosives will give the same results as those bearing the same name abroad. Considering the magnitude and importance of the coal-mining industry in Great Britain, it does not seem too much to expect the Home Secretary to decide this question. He has chosen not to do so, hence it is necessary to realize that the Woolwich tests do not guarantee the safety of "permitted explosives," or a sense of false security may arise which eventually must lead to disaster.*

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* While the author was writing this paper, another by Mr. Gattmann on "Safety-explosives" was issued in the *Journal of the Society of Chemical Industry*, 1899, vol. xviii., page 6, to which reference may be made.

Mr. W. H. CHAMBERS, who took the chair on Mr. Holford leaving the meeting, said that members would agree with Mr. O'Shea that they were working in the dark in this country with regard to the information which they ought to have concerning the employment of explosives. The members knew more about the principles of these explosives in which they were so closely interested, with which they risked their lives to a considerable extent, than the Home Secretary who told them what to use.

Mr. G. B. WALKER (Wharncliffe Silkstone Colliery) said that the subject of explosives was a labour of love to Mr. O'Shea. When he came to Sheffield he had no idea of identifying himself with the mining industry, but since he had identified himself with it he had spared neither time, trouble, nor money in their behalf, and his one disappointment was that there was so little interest in the subject aroused amongst colliery-managers and proprietors. Recently, a committee constituted of members of the two Institutes made suggestions with regard to the erection of an experimental explosives testing-plant, and he failed to see why they should allow year after year to go by without putting their views into practical shape. The members did not appear to realize that they did not obtain any guarantee from the Government as to the relative safety of the different explosives which they were authorized to use. The members could not take the twenty or thirty permitted explosives, and say that they were all equally safe. If the members were of opinion that the Institutes should erect an explosives testing-gallery, he believed that the £1,200 requisite would be readily subscribed. He urged upon the members to erect a plant, so that such experiments as seemed desirable could be made under the practical conditions of mining operations.

Mr. H. B. NASH, in supporting the vote of thanks to Mr. O'Shea, said that he entirely disagreed with Mr. Walker's suggestion. He thought that the Mining Institutes should bring sufficient pressure to bear upon the Government through members of Parliament representing mining constituencies, and force the Home Secretary to establish a testing-station worthy of the nation. It was essential that perfect tests should be made in this country upon explosives, whether on the permitted list or not, and that the results should be published by official authority.

Mr. O'SHEA, replying to the vote of thanks, said that the question of explosives was to him one of considerable interest. It was an old love, many years ago he was connected with the manufacture of explosives, and he now found himself associated with their use. In this country the testing of explosives was placed in the hands of H.M. inspectors of explosives, and it seemed to him that it would be desirable for a committee representing the coal-mining industry to meet H.M. inspectors of explosives and endeavour to draft a satisfactory code of procedure for the testing of explosives. He could sympathize with members who thought it the duty of the Home Secretary to make all tests, but if he would not do so they must take the consequences, and use what the Home Secretary told them, or set to work and test explosives for themselves. If the time came when a gallery would be erected in this country for testing explosives on satisfactory lines, he should feel that it was a happy day for the mining industry. The members might gather from results which had been obtained abroad some ideas as to the conditions which regulated the safety of explosives in mines, but they could not rely on the actual results applying to the same explosives in England. So much depended on the composition of explosives in the first instance, explosives having the same name abroad and in Great Britain had often different compositions. They could only look upon results obtained abroad as giving a general idea of what they might expect.

The following paper on "The Use and Abuse of Colliery Locomotives," by Mr. W. W. Clayton, was read:—

THE USE AND ABUSE OF COLLIERY LOCOMOTIVES.

By W. W. CLAYTON, M.Inst.M.E., M.Inst.C.E., and M.I.Mech.E.

As it was a colliery-owner who first used a locomotive engine as a commercial success, a brief account of its early history may be interesting to the members.

In the year 1811, John Blenkinsop, who was then the proprietor of the Middleton colliery near Leeds, ordered from Matthew Murray, an engineer in Leeds, a locomotive for use on his colliery-railway. This engine started work in August, 1812, its weight was between 4 and 5 tons, and it was propelled by means of a toothed wheel working in a rack at one side of the rails. It regularly hauled 30 coal-waggons, weighing altogether about 94 tons, at a speed of 3½ miles an hour.

Trevithick, a Cornish engineer, was at the same time experimenting with the locomotive, and built one for Blackett, of Wylam; for some reason or other this engine never worked on the railway, but was used for another purpose at the colliery. William Hedley, the viewer, however, was not content to let the matter rest: he set to work to improve upon the engine, and after making exhaustive experiments as to whether the ordinary adhesion of the wheels of an engine working upon smooth rails would be sufficient to ensure the useful application of the whole of the steam force, he built an engine to work on his plan. It had a cast-iron boiler and one steam-cylinder 6 inches in diameter. This engine, though much superior to Trevithick's, was still very unsatisfactory; he therefore built another one, with a larger boiler of wrought-iron and two steam-cylinders. This was the first locomotive to work successfully by its own adhesion on smooth rails. It was called the "Puffing Billy," and is now in the South Kensington Museum.

George Stephenson, who had watched Hedley's experiments from the first, recommended the proprietors of Killingworth collieries, where he was employed as enginewright, to adopt locomotive power. An engine was built in the colliery-workshops which was practically a failure; but Stephenson was not to be beaten, and a second engine was built at Killingworth in which many of the most serious defects were remedied.

It continued working on the colliery-line for many years, and its success decided the directors of the Stockton and Darlington Railway in 1822 to adopt steam-locomotives for their line.

Such, briefly, is the history of the locomotive to its first use on a public railway, and though the celebrated trials at Rainhill did not take place until (some years afterwards) October 1st, 1829, its success was now fully assured.

Locomotives used at collieries, leaving out of the question large tender-engines sometimes employed, are tank-engines having inside or outside cylinders, and are carried on four or six coupled wheels. The tanks are variously placed: the most common and certainly the best form is the saddle-tank placed over the boiler-barrel, and sometimes extending over both smoke-box and fire-box. Side or wing-tanks are placed on each side of the footplate, partly with the idea of improving the appearance, which they undoubtedly do, and partly to lower the centre of gravity of the engine; but as the water is carried farther away from the centre of the engine, this is only done to a small extent. In small engines, side-tanks are a great disadvantage, as they interfere with the access to the motion-bars inside the frames. Under-tanks, placed under the boiler-barrel and between the frames, are the most objectionable of all, as they block up entirely the access to the front of the fire-box shell for washing out purposes.

Whether inside or outside cylinders are best is a question that has been much debated, but there is no doubt at all that outside cylinder-engines are simpler and cheaper to build, and are therefore more suitable for rough usage than inside cylinder-engines. In America, Russia, and many other countries, engines with inside cylinders are entirely unknown. It is quite possible to build outside cylinders in such a manner that there is no possibility of their becoming loose. The drawing (Fig. 1, Plate III.) shows an engine with a pair of cylinders (16 inches in diameter) which have been working for 30 years, and not a single bolt has been renewed.

The choice between engines on four or six wheels depends entirely on the curves upon the railway and the speed intended to be run. The slower the speed the sharper may be the curves which the engine will traverse in safety. About collieries, curves should always be laid wide to gauge, giving say ½ inch in 150 feet curves to as much as 1 inch in 40 feet curves. Six-coupled engines, with a 12 feet wheel-base, will readily pass round 150 feet curves laid in this manner, especially if the flanges of the driving-wheels are thinned. This thinning of the flange of the central wheels adds very considerably to the life of the crank-axles, as it reduces very considerably the nip of the rails, the most destructive force against which they have to contend.

As a general rule, four-wheeled engines may be used up to 22 tons in weight, heavier than this (unless the roads are good) they are very destructive, and especially so if made with short-wheel bases, say under 6 feet. There is no difficulty with engines of 7 feet wheel-base working round curves of 40 feet; but over 20 tons in weight engines with six wheels are much to be preferred, and their economical working on rough roads may be greatly assisted if they be properly placed on suitable springs.

The spring-gear should be so designed that when the engine is standing on an uneven road the distribution of the weight on the wheels should not be materially altered. There are various ways of accomplishing this object. One is by placing equalizing levers on each side of the engine between the ends of the springs. Another way is by placing a large cross-spring pivotted in the centre at the trailing-end of the engine. The latter arrangement has the additional advantage of leaving the driver's footplate clear of springs.

The proper proportions of springs is an important factor not only in the economy of the engine and rails, but also adds greatly to the comfort of working. They are often too short, too narrow, too deep, or have too much camber, and when all these faults meet together a lump of cast-iron would answer equally well. Figs. 2 and 3 (Plate III.) show such a spring, and Figs. 4 and 5 one of equal strength and of good proportion. In a wide spring, the hole through the centre, which is the ordinary method of manufacture, is a much smaller proportion of the total section than in a narrow one. It is, however, not always possible in designing locomotives to get in exactly the spring that one would wish.

Some engineers have the impression that the greater is the number of brake-blocks the greater is the efficiency of the brake. Such, however, is not the case, as friction is proportionate to weight and not to surface, therefore two blocks acting on two wheels are as efficient as six blocks on six wheels. Brake-blocks wear the tyres very considerably, and for this reason it is desirable to have a block on each wheel to ensure equal wear of the tyres. Cast-iron blocks, covering the flange as well as the tread of the tyre, are the best to use. As the size and weight of trucks have increased greatly, requiring the use of larger engines, steam-brakes are now almost a necessity to relieve the drivers of the hard labour that constant braking entails. Reducing-valves should always be used in connexion with steam-brakes, so as to properly control their action.

The most important part of a locomotive is the boiler, which is now usually made of mild steel plates; but whether this material is the best for the purpose is not a settled point. With bad water best Yorkshire plates last better.

Boilers should be so fixed and carried that none of the strains to which the frames are subjected should be transmitted to them. They should be firmly bolted, both tube-plate and smoke-box, to the cylinder, so that no movement can possibly take place, ensuring a rigid connexion for the steam-pipes.

At the fire-box end, proper provision should be made for expansion, which is best obtained by means of a clasp over the angle-brackets at the sides of the fire-box shell. Bolts placed through slotted holes (Fig. 8, Plate III.) are objectionable, as they are liable to get fast. The two sketches, Figs. 6 and 7, (Plate III.) show two different arrangements.

It is of the greatest importance to watch carefully that the provision for expansion does not become inoperative, as when this occurs enormous strains come on to the boilers, causing trouble with the vertical seams, leaky tube-plate angles, and often cracking the corners of the fire-box shell-plate.

The practice of cramming boilers with a large number of small tubes is a very objectionable one, being often done to make an imposing show of large heating-surface; but as the relative value of tube heating-surface is only one-tenth that of the fire-box, leaving out a few tubes is never felt, and the extra space gained between each tube is a great advantage, and extra strength is left in the copper tube-plate.

What is the best material for tubes is a question which can only be decided by the conditions of working at each particular place. Brass tubes will not answer at all with gas-coke or coal containing a large amount of sulphur. The tubes will thin very rapidly immediately in front of the ferrule at the fire-box end and collapse in a few months. Steel or iron tubes answer very well for such fuel, and provided the water contained no free acid, would be the best to use. When both fuel and water are bad, copper tubes are the only ones that will stand. Care should always be taken that the tubes project through the tube-plates, as these depend entirely on the tubes for their support, and when these are allowed to get within the plates, bulging inevitably takes place. Iron and steel tubes are often put in with a copper end, on account of the idea that they cannot be made tight in the fire-box tube-plate without this. There is no difficulty in making a steel tube tight in a copper plate, if care be taken to have the tube thoroughly clean and bright, so that there is perfect metallic contact between the tube and the plate.

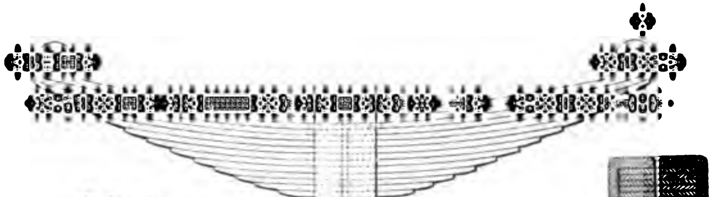
The boiler is undoubtedly that part of the locomotive which comes in for the greatest share of abuse, mostly from the use of unsuitable water.

Absolutely pure water is very bad for boilers, as no protective scale is formed on the surface of the plates, consequently corrosion takes place very rapidly, and is indicated by the presence of rust in the water-gauge glass.

Water containing magnesia is very troublesome to use, but does not act injuriously on the plates: with such water, after working a short time a thick scum forms on the top of the water; the steam having to rise through this carries with it particles of magnesia loaded with moisture, and excessive priming is the result. A partial remedy for this is the use of a scum-cock, but, as the water-surface in a locomotive boiler is much broken up with stays, effective scumming cannot take place, and frequent emptying and washing-out of the boiler must be resorted to.

Water containing lime in various forms is most commonly used, and this generally forms a hard scale on the plates. There are many remedies for this in the shape of boiler-compositions, but all that is required is that the solids left in the boiler from the evaporation of the water should be in such a state that they can be readily removed. In stationary boilers this removal has been very successfully accomplished by means of petroleum, the only difficulty experienced being to get it into the boiler in a small enough quantity and in a finely divided state. It has been tried in locomotives by painting the inside of the water-tank with the oil, and, though it answered the purpose, some more convenient method will have to be found out before its use can be generally adopted.

The regular washing out of boilers is often neglected—simply blowing the water out of the boiler is by some considered all that is necessary. The practice of blowing-off boilers is a most barbarous and damaging proceeding; it ought never to be allowed, and the sooner blow-off cocks are entirely dispensed with, the better it will be for boilers. The steam should be allowed to go down quietly, the boiler emptied, and the washing-out not proceeded with until the boiler is nearly cold. The use of copper instead of iron rods in the mudholes would very materially save the threads in the holes, and the plates at the bottom of the fire-box shell.



Reference

Span of Spring ..... 3 Feet.

No. of Plates 14

Width of Plates ..... 5 Inches.

Thickness of Plates $\frac{3}{8}$ Inch

Pin-hole reduces width of plates by $7\frac{1}{2}$ per cent.

Fig. 4.

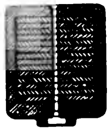


Fig. 5.

Scale, 1 Foot to 1 Inch.

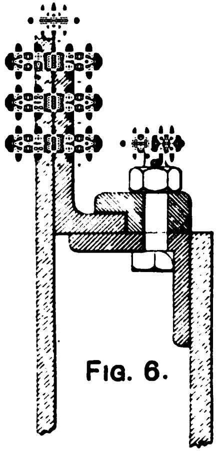


Fig. 6.

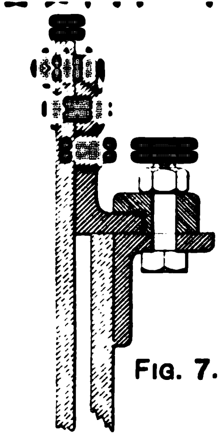


Fig. 7.

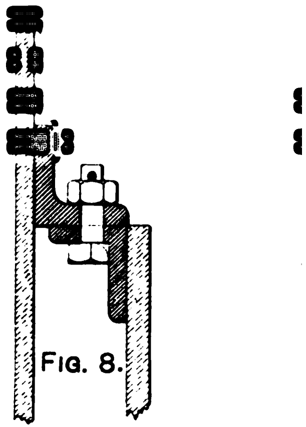


Fig. 8.

Scale, 6 Inches to 1 Inch.

terfield and Midland Counties Institution of Engineers.
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Andw Reid & Compy Ltd Newcastle on Tyne

Vol XXIII, Plate 1.

The provision of efficient means for constant lubrication of all the working parts of an engine is a matter to which builders should give careful attention, but it is just as important that users should provide suitable lubricants. It is absurd to expect good results from the commonest mineral oil that can be obtained, and the use of such oil adds very seriously to the cost of repairs. The old-fashioned tallow cock is another thing that could very well be omitted, and sight-feed lubricators should be adopted, as they ensure a constant supply of oil to the steam-cylinders.

Much might be written as to the proper method of cleaning engines, but it is impossible within the scope of a short paper to deal exhaustively with such a complex structure as a locomotive-engine. Though the fringe of the subject has only just been touched, the foregoing paper may lead some of the members to take a greater interest in the subject, and possibly may tend to the better use and the less abuse of colliery locomotive-engines.

Mr. W. H. CHAMBERS moved a vote of thanks to Mr. Clayton for his interesting paper.

The CHAIRMAN seconded the proposal, which was carried unanimously.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,
APRIL 8TH, 1899.

MR. WM. ARMSTRONG, PRESIDENT, IN THE CHAIR.

The **SECRETARY** read the minutes of the last General Meeting, and reported the proceedings of the Council at their meetings on March 25th and that day, and of the Council of The Institution of Mining Engineers.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. **HENRY CLARK**, Engineer, Cowper House, Norton, Stockton-upon-Tees.
Mr. **JOHN COULTHARD**, Certificated Colliery Manager, Brunnerton, Greymouth, New Zealand.
Mr. **HUGH LLEWELLYN GILL**, Mechanical Engineer, c/o Messrs. Bennie, Teare & Co., Woodward Street, Coolgardie, Western Australia.
Mr. **HENRY WALLACE GREGORY HALBAUM**, Certificated Colliery Manager and Journalist, 12, Kelvin Grove, Gateshead-upon-Tyne.
Mr. **PAUL MELLORS**, Copper-mine Manager, Locksley House, Sherwood Rise, Nottingham.
Mr. **GEORGE BENTLEY POORE**, Mechanical Engineer, P.O. Box 149, Johannesburg, Transvaal, South Africa.
Mr. **JOHN SOUTHERN**, Colliery Manager, Heworth Colliery, Felling, Co. Durham.
Mr. **FREDERICK T. SNYDER**, Metallurgical Engineer, c/o The William Hamilton Manufacturing Company, Peterborough, Ontario, Canada.

ASSOCIATE MEMBER—

Mr. **ARTHUR KIDSON**, Argyle House, Sunderland.

ASSOCIATE—

Mr. **JOHN THOMAS MELVILLE**, Surveyor, Coxlodge Colliery, near Newcastle-upon-Tyne.

STUDENT—

Mr. **JOHN ROGERS**, Mining Apprentice, Cornsay Colliery, Durham.

AWARDS FOR PAPERS.

The **SECRETARY** read the following list of papers communicated during the year 1897-98, for which prizes of books had been awarded by the Council to the authors: –

"Pyritic Smelting." By Mr. W. Lawrence Austin.
"Experiments with the Shaw Gas-tester." By Messrs. P. P. Bedson and J. Cooper.
"Notes on Rearer Workings." By Mr. John Cadman.
"Occurrences and Mining of Manjak in Barbados, West Indies." By Mr. Walter Merivale.
"The Siliceous Iron-ores of Northern Norway." By Mr. H. T. Newbigin.
"The Gold Regions of Alabama. U.S.A." By Mr. Wm. B. Phillips.
"Hydrothermal Gold-deposits at Peak Hill, Western Australia." By Mr. Frank Reed.

DISCUSSION ON MESSRS. J. L. HEDLEY AND W. LECK'S PAPER ON "TIMBERING IN THE IRON-ORE MINES OF CUMBERLAND AND FURNESS."*

Mr. T. E. **FORSTER** (Newcastle-upon-Tyne) remarked that, in the discussion which followed the reading of the paper, exception was taken to the Cumberland practice of timbering, some of the speakers thinking it a bad system to put a round balk on a fork-prop. It might be wrong in theory, but from what he had seen of the iron ore-mines in Cumberland props were very rarely split. Although the system of square timbering had not been followed up in the Cumberland district, he thought it would be interesting to have a description of that method. He would like to know to what extent the ore was taken out of the vein-like deposits, which were described in the paper, and the space between, standing on chocks or setts. Did they find the hanging-cheek come in at any time? It appeared to him that it would only go so far, and then there would be a crush.

The **PRESIDENT** said that each district adopted the system which suited it best, and he thought that any application of timbering in one district would not entirely suit another.

Mr. G. B. **FORSTER** (Newcastle-upon-Tyne) said that in Cumberland the props were generally set with the thin end downwards, and it was found that putting a balk on the top did not split the thick end so much as the thin end.

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* *Trans. Inst. M.E.*, vol. xvi., page 281.

Mr. J. L. **Hedley**, replying to the discussion, said that the American system of square timbering was tried at the Hodbarrow mine, but had been discarded because it was not profitable. In this system, the timbering was begun from the bottom of the deposit. In many of the mines in the Furness district, it was necessary to work from the top downwards, and therefore the American system could not be used to advantage. The system had, however, been recommenced on a smaller scale, and with additional experience gained by previous trials, the results would be specially interesting. The question of timbering was one which required very much consideration, and it was necessary to adopt many and various systems. It would be readily understood that it was necessary to adopt a system of timbering in the Furness deposits different from that in use in Cumberland, where they had deposits of a different character. There were scarcely two mines in his district in which a similar method of timbering was used.

Mr. W. **Leck** remarked that the timbering of vein-like deposits was among the most difficult of the mining problems with which they were called upon to deal, and no doubt it sometimes did happen that falls took place from the hanging side. The sides of the veins were very irregular, and occasionally they came close together and then widened out again. Where the vein became very narrow, the timbering was sometimes filled in with "deads," and thus there was practically a solid mass between the two sides. A few years ago, they had a very striking example in connexion with these veins, when there was a sudden collapse of surface, and a locomotive engine disappeared, which had not been recovered. The veins varied in thickness from 2 or 3 feet at one point to 30 or 40 feet at another.

Few persons had better opportunities of going through these mines than himself, and he found that whether their method of connecting the fork-prop and cap was right or wrong in theory, as a matter of practice, which, after all, was but the result of experience, the actual effect was satisfactory, and few fork-props were split. This particular system was universally adopted in the Furness and West Cumberland mines, including Hodbarrow, to which mine many of the miners had migrated from Cornwall.

DISCUSSION ON MR. W. T. GOOLDEN'S PAPER ON "COAL-CUTTING BY MACHINERY."*

Mr. A. L. **Steavenson** (Durham) said that one point which struck him on reading the previous discussion on this paper was the very great divergence of opinion on the part of electrical engineers and mining engineers with reference to electrical coal-cutters. One recommended 300 volts, another 350, and a third 500, and so on, and those who were not electricians were rather confused. They were told by Mr. Goolden that he had received a shock of 600 volts without injury—that might be so; but he had read of a case in Scotland where a man was lifting a tub on the rail, and when his bare head touched the conductor—carrying 200 volts—he fell dead. He had been using currents of 300 to 350 volts for many years. Another thing to be considered, not only in regard to destroying a man's life, which was sufficiently serious, was that if the men received shocks they might refuse to work with electricity, and the plant would be thrown on one's hands.

Another point on which there was considerable difference of opinion was with regard to the multiphase system. One electrician would recommend the multiphase system for certain purposes, and another would say that they must not adopt it on any account. In such cases, he thought that each should ascertain for himself as far as he could what was the best system.

Mining engineers also differed in regard to the use of the cutters:—One said that they were only useful in thin seams; another said that they were useless in seams above 3 feet; and somebody else averred that they could be worked with advantage in seams 4 or 5 feet thick. No doubt if they were to save money at all by coal-cutting, it would prove more effective in thin than in thick seams. The percentage of undercut was twice as great in a 2 feet seam as in one of 4 feet, and therefore if machines would not pay in a 2 feet seam, they were not likely to do so in thicker seams.

There was a considerable difference in the manner in which costs were compared. He thought that there was only one fair way of doing this, and that was to take a case where both systems had been adopted and to take a fortnight's pay-bill, at different times, say in 1896, when the entire cost was for hand-labour, and another pay-bill, say for 1899, when practically all the work was done by coal-cutting machines.

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* *Trans. Inst. M.E.*, vol. xv., page 378.

Electricians complained that slow progress was being made in regard to the introduction of coal-cutting machines; and the United States of America were quoted in comparison; but it was pointed out by other speakers that if the total coal produced in America was compared with the quantity produced by machines, the latter amounted to only 7 per cent. He thought that, after all, they were not very far behind the Americans or their friends on the Continent.

The efficiency of electric plants was so much a matter of opinion, that he might state his own experience in Cleveland with electricity, as compared with compressed air. For 20 years, compressed air had been used in mines about 2 miles from one end to the other, with numerous machines, so that it was impossible to make a direct test, and say that they would start at a given hour and indicate every engine. He had managed to obtain a result by taking diagrams over several hours with each system of engines at bank, and these showed that with compressed air 111 horsepower was required for 8 drills. With electricity, about 17 horsepower was required for the same work. The great loss with compressed air arose from the leakages of some 8 or 9 miles of pipes, whether the drills were cutting or not.

There were certain conditions where he thought every mining engineer was agreed that they would not adopt electricity; and some would say that they would not take electricity where candles could not be used. To meet this difficulty, he would suggest: Supposing the coal-cutters were 5,000 feet in-bye; at say 4,000 or 4,500 feet, they might place an air-compressor and work it by an electromotor. They would thus get the advantage of the saving between the shaft-top and the 4,500 feet, and the safer conditions of using compressed air at the face.

In using electric machinery, it was essential that a responsible person should be appointed to attend to it, else the manager or under-manager would find it troublesome, and in time it would be relegated to the scrap-heap.

Mr. J. L. Hedley said that if danger arose from touching an exposed cable, it was questionable whether electric wires should be used down the pit. There was also the liability to sparking, and the question arose whether these sources of danger could be removed.

Mr. C. C. Leach (Seghill) said that, even when a cable became damaged, there was no more danger than from a damaged steam pipe, and both would be at once repaired. He had taken hold of cables, without danger, carrying a current of 460 volts. He did not agree with

Mr. Steavenson with regard to the difficulty of ascertaining the useful effect. If they took the indicated horsepower of the engine and compared it with the useful work, the useful effect of the electric-plant at Seghill colliery was 32 per cent.

Mr. T. E. **Forster** asked what voltage an average man could take without danger.

Mr. H. W. **Appleby** (Bradford) thought that mining engineers were themselves to blame for the different voltages adopted by the various makers, who, in the present competition in the electrical trade, adapted their goods to the people whom they supplied. He had generally found, with coal-cutting machines, that there was a saving of 10d. per ton in working a 2 feet seam as compared with hand-holing. A similar result was obtained at Lidgett colliery, near Barnsley, where a large number of machines were at work. He was of opinion that all cables should be properly insulated and covered. He thought that the difficulty of broken cables could be overcome by laying the cables on the ground in preference to attaching them to the roof. The dangers arising from a broken cable were much greater in a fiery mine than the sparking from the commutator—the latter danger was very much exaggerated, as most motors used in mines were enclosed and gas-tight.

The working of a 3 or even 2 phase-system did away with the commutator, but it necessitated more cables and thus increased the danger to a greater extent than it lessened it by doing away with the commutator.

With reference to the danger from high pressure, he had received a shock of 500 volts without injury, but this could not be done by any man in a weak state, or whose hands were moist, and, under such conditions, 250 volts might prove dangerous.

Mr. T. H. Barr stated in his paper that the amount of power required depended upon the class of holing and the depth of the cut, and might vary normally from 12 to 20 horse-power.* He thought that 50 or 60 horsepower would be more nearly correct. Of course it must be understood that this over-load was only for short periods. He did not intend to state that 50 horsepower was the constant load of the machine, but that they had to work up to that power very frequently for a few minutes at a time. Motors designed for 23 horsepower were nearly always run at more than double, but the load never came down so low as was estimated by Mr. Barr. He had tried a 14 horsepower motor, but it was always burning out and breaking down, and it was replaced by a larger one of 23 horsepower designed to run at double load if necessary. This worked excellently, and seldom gave any trouble. With reference to the Hurd coal-cutter, he would like to ask Mr. Goolden, who made a machine of the same type, whether it did not happen, when it came to a hard place in the coal, that it cut up above it or ran below, choosing the easiest part.

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* *Trans. Inst. M.E.*, vol. xvi., page 450.

Mr. W. T. GOOLDEN, referring to Mr. A. L. Steavenson's interesting remarks, wrote that it was much the same with electricity as with steam. The particular voltage or particular steam-pressure at which an engineer would prefer to work must depend on the special circumstances of the case, and no hard-and-fast rule could be adopted to meet every condition. Economy in space, and in some degree in first cost and working expense, tended to high pressures both in electricity and in steam. Considerations of convenience and of safety might tend the other way, and generally some compromise was arrived at.

As regards the thickness of seam in which it was most profitable to work a coal-cutter, here again no hard-and-fast rule could apply. It was naturally more difficult to work in a very thin seam either by machine or by hand than in a place where there was plenty of room. The yardage would in general be much greater where there was plenty of head-room, and the machinery could be more thoroughly and expeditiously overhauled and repaired than in a cramped situation. Another consideration, which was generally overlooked in estimating the comparative advantages of machine-cutting and hand-cutting, was the value of the product. If a machine of ample power and strength of material was used, so that the face could be quickly worked, the coal produced was generally of so much better appearance that an enhanced price could be obtained for it. Therefore not only the pay-bills, but the invoices, should be compared in the two periods suggested by Mr. Steavenson. He (Mr. Goolden) was preparing a full and detailed account of the costs actually incurred in a number of pits where machines had been working during the last 6 years, which he hoped to be able to lay before the members at a no distant period.

The comparative efficiency of compressed air and electricity experienced in the Cleveland mines yielded so remarkable a result that it was well that it was given on the authority of so trustworthy and independent an observer as Mr. Steavenson.

The suggestion made by Mr. Steavenson of using a motor-compressor for great distances in-bye is a plan that he (Mr. Goolden) had advocated for some years past, and the figures given by Mr. Steavenson fully justified it.

It was not, however, necessary to engage an electrical expert to look after electric mining-machinery, provided that the plant was well made and had a sufficient margin of power. There were several mining-plants which had been running for many years under the care of colliery-engineers, without any trouble or technical assistance whatever. The repairs were easily made by the ordinary colliery staff, and his (Mr. Goolden's) experience compelled him to state that as a rule they were better done than when they were sent away to the manufacturers' repairing shops. It was not a difficult matter to rewind an armature; it simply required care, and that care was more likely to be given by the workman who was responsible for running the machine, than by a workman who never saw the machine again after it left his hands.

In reply to Mr. Appleby's question whether a bar-machine when it came to a hard place in the coal, chose the easiest path above or below the obstruction, it was a fact that with a light machine this did occur, and a machine had once or twice been lifted completely off the rails in this manner, but with the heavier machines now used, this did not occur. If the rotation of the bar was reversed, the tendency was to go below an obstruction. In this case there was less chance of getting the machine off the rails, and the cutting was often much steadier and more regular.

Mr. T. H. Barr was correct in his statement of the lower limit of power required by a coal-cutter. A good deal of work with a bar-cutter had been done with 35 ampères and less than 300 volts, that was, absorbing 12 to 14 horsepower; on the other hand, the power had frequently risen to 37 horsepower, and would no doubt have exceeded this but for the fuses blowing. A disc-cutter, working on a material which a bar-cutter could not tackle at all, might exceed this higher limit considerably.

Mr. T. L. Elwen read the following "Notes on the Glacial Deposit or 'Wash' of the Dearness Valley."

NOTES ON THE GLACIAL DEPOSIT OR "WASH" OF THE DEARNESS VALLEY.

By T. L. ELWEN.

The river Dearness rises near Tow Law, some 10 miles west-south-west from the city of Durham, and flows for 10 miles in an easterly direction, to its junction with the river Browney near Langley Bridge. It has a total fall of about 700 feet, or from 900 feet to 200 feet above sea-level, and a mean width of about 12 feet. In its course it is fed by several small streams, which also form "washes" on a smaller scale, for a short distance up the side of the valley. After its confluence with the river Browney, at a further distance of 3½ miles, occurs the confluence of the river Browney with the river Wear near Croxdale. The "wash" described in these notes may therefore be regarded as a tributary of the larger or principal wash of the Team valley.

The Dearness valley is well-developed laterally, being enclosed by well rounded hills rising to a height of 400 feet above the present level of the river at its lower reaches, and having a width between the summits of about 2 miles.

Geologically, the valley is situated in the Upper Coal-measures, with the exception of the recent deposits of clay, sand, etc. The coal-seams, which are continuous throughout, have a total rise of 1,100 feet, which is in excess of the surface-rise by 400 feet. The proved workable coal-seams in the strata at the termination of the valley, from the top of the series, are :—The Hutton, Harvey, Busty and Brockwell. The Hutton and Harvey seams outcrop naturally, apart from glacial action, in their order up the valley.

A deposit of Boulder Clay, near the surface, is present all along the valley. It rests on the Coal-measures, and is overlain by thin beds of sand and gravel. It is an irregular, unstratified and very compact deposit, having a maximum thickness in the lowest parts of the valley and thinning out towards the summits of the hills.

Proceeding in the direction of the valley, the base of this deposit is seen to be of an undulating character, and consequently variable in thickness. It thus lies in depressions, the river flowing generally over the deposit is absent

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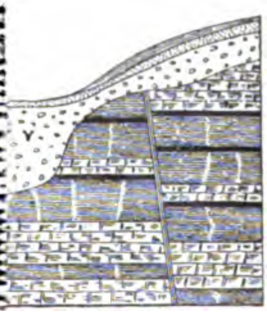

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found any fossiliferous remains in this deposit. Resting on the top of the clay is a bed of sand, gravel and large boulders, with pieces of decayed wood, and it is full of water. Beds of sand and boulders with water intercalated in the clay are present in some parts of this deposit.

The period during which the faulting occurred in the coal-seams appears to have been antecedent to this deposit, as no trace of them has been found in the clay. The effect of this Glacial Drift, primarily, in cutting out large areas of workable seams, and secondarily in subjecting the adjacent areas of coal to deteriorating atmospheric agencies is considerable. To what extent separately, the effect of glacial action and that arising from other natural agencies, is a matter of conjecture. A considerable thickness of strata with the enclosed coal-seams must have been scooped out of the valley by ice. An additional effect has been the subjection of the lower seams to the deteriorating action of atmospheric agencies by removing part of the natural cover.

The coal-seams under this deposit, which are situated less than 100 feet from the surface, are found generally to be deteriorated, though the same seam will resume its normal quality where the thickness of older rock-cover increases, found by following the contour-lines to the rise and by approximating—if the information is not at hand from the lower seams—the levels of the strata, and also by an examination of the surface to discover whether the Boulder Clay exists there or not. Thus, a coal-seam considered useless in the lower parts of the valley may exist in good condition in small areas higher up. This reasoning is complicated somewhat by the fact that the Glacial deposit lies in hollows : for where the Drift is developed, the bottom of the deposit (for all practical purposes) may be considered the surface,—such it would be during the Glacial period—and, consequently, the upper coal-seams would be deteriorated in quality.

The drainage-level also must be taken into consideration. The average inclination of the seams up the valley is 1 in 48, and being considerably in excess of the surface-rise, brings the top-seams successively above the drainage-level. Water would consequently percolate through the joints of the coal, reducing the quality by removing the enclosed gases, and leaving behind sand- and dirt-partings of a red colour. Thus in the same seam approaching this deposit the coal is deteriorated on each side of the wash-out to a greater width higher up the valley, where the coal has remained above the river-level, than lower down the valley, where the seam would be above the drainage-level during the Glacial period only. This process would be assisted by the gullety nature of the upper strata, which would form both water-channels and outlets for gas from the coal. To some extent to the action of alternating extreme colds during the Glacial period may be attributable the broken-up character of the strata surrounding the deposit.

Mr. A. L. Steavenson (Durham) said that about 35 years ago they had a paper on the Team valley wash by the late Mr. E. F. Boyd and Mr. Nicholas Wood. This paper gave a very excellent account of the Team valley wash, and was illustrated with sections. A similar wash extended into Weardale, where they were cutting it with a steam navvy, when baring the limestone.

Mr. Philip Kirkup (Cornsay) said that he did not quite understand the statement as to the total rise of the strata being 1,100 feet. On a line between Stanley pit and Hedley Hill colliery, the Brockwell coal-seam outcrops at about 50 feet above the bed of the stream, on the south side of the valley. The base of the "wash" at this point is approximately 100 feet below the bed of the river Dearness, so that the ancient river or glacier had really scooped out rocks below the Coal-measures, in fact 150 feet into the Ganister series. All the coal-seams deteriorated in quality as the "wash" approached them. The red colour in the cleavages was caused by oxide of iron. He would like Mr. Elwen to produce some of the striated stones which he believed must be more common in the lower portion of the valley than in the upper. He had found boulders of basalt, greenstone, sandstone and blue limestone in the clay.

Mr. T. L. Elwen said that he arrived at the rise of strata as 1,100 feet by taking the depth of the Brockwell seam, 600 feet in the lower reaches of the river, and adding to this the natural rise at the surface, 500 feet, obtained from the Ordnance survey-maps, he obtained a total rise of 1,100 feet. He would exhibit some of the striated stones at the next meeting.

The President moved a vote of thanks to Mr. Elwen for his paper.

Mr. P. Kirkup seconded the resolution, which was cordially approved.

Mr. F. Reid's paper on "The Felling of a Chimney" was read as follows:—

THE FELLING OF A CHIMNEY.

By FRANK REID.

The following is a short account of the felling of the large chimney at Wallsend on January 14th, 1899.

This chimney was built in 1879, and being no longer required, the present owners of the ground (The Parson Steam-turbine Company, Limited) decided upon its removal.

The chimney was 266 feet high, at the ground-level the outside diameter was 21 feet, and the inside 14 feet; and at the top the outside diameter was 14 feet, and inside 12½ feet; making the brickwork 3½ feet thick at the bottom and 9 inches at the top.

On examination, the writer came to the conclusion that he could fell the chimney in a nearly due south direction, where the ground was clear of all buildings.

On January 9th, 1899, the workmen commenced cutting out the walls on both sides of the chimney, about 3 feet from the ground, working towards the point of direction of the fall, and as the brickwork was removed it was replaced with large wooden blocks 18 inches high, 15 inches wide, and 12 inches long, carefully wedged up with thin hardwood wedges. The wooden blocks consisted of three deal boards, each 18 inches long, 3 inches thick, and 12 inches wide, and each board was separated by two pieces of deal 7 inches by 3 inches by 12 inches, in order that tar and sawdust might be filled into the interstices and afford a larger burning surface (Fig. I.). About 40 feet was cut out, and the chimney being at this point 66 feet in circumference, about 26 feet was left at the back.

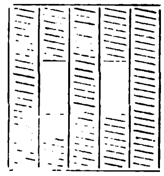

Fig. 1.—Elevation of a Wooden Block.

The blocks being saturated with tar and paraffin, wood was then built for a fire all round the circumference of the chimney where the brickwork had been removed, the firing-material being much larger at the point of direction of the fall of the chimney. For about 1 minute after the fire was lit, workmen were employed throwing paraffin on the portion where

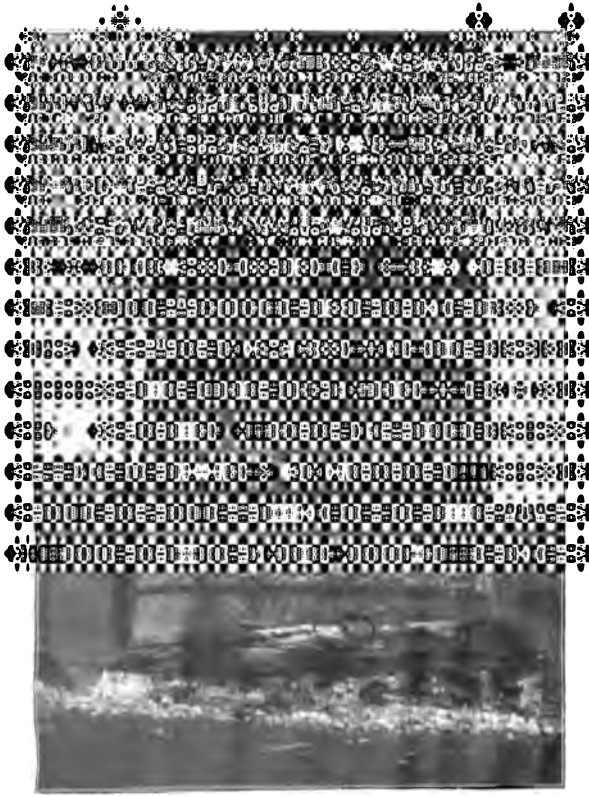

FIG. 2.—View of Chimney, with Firing-material ready for Ignition.

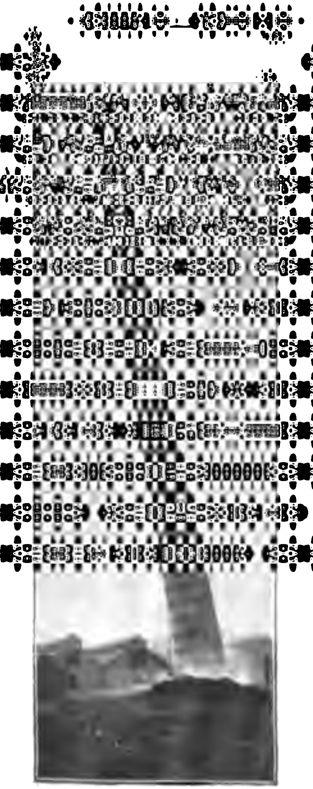

FIG. 3.—Falling.

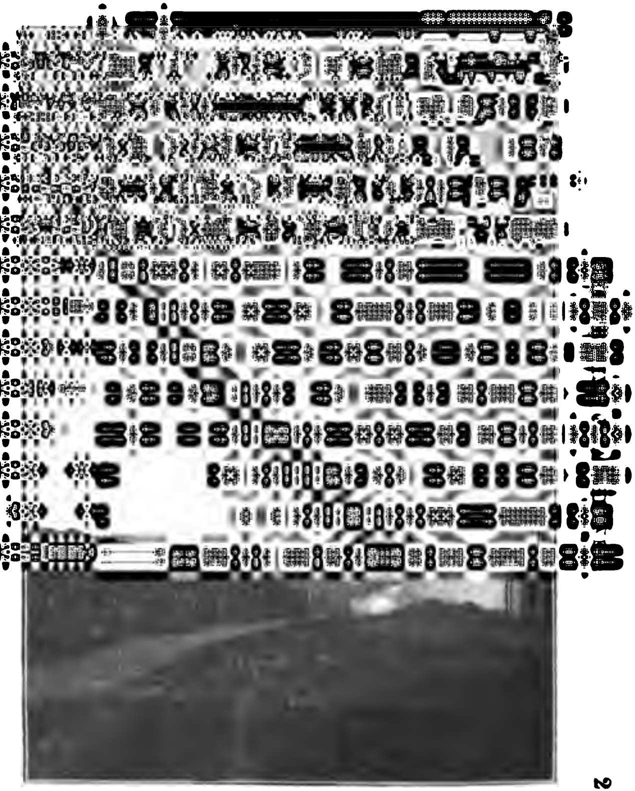

FIG. 4.—Falling.

the blocks were required to burn most rapidly, and 6 minutes after the lighting of the fire, the chimney fell exactly on the line marked out for it on the ground.

The cost of felling the chimney was only half of that involved in its removal by ladders and throwing the material down, working from the top; and moreover many thousands of the bricks were recovered for further use.

The PRESIDENT moved a vote of thanks to Mr. Reid for his interesting paper, and it was cordially approved.

The meeting then terminated.

SOUTH STAFFORDSHIRE AND EAST WORCESTERSHIRE INSTITUTE OF MINING ENGINEERS.

GENERAL MEETING,

HELD IN THE MASON UNIVERSITY COLLEGE, BIRMINGHAM, MAY 4TH, 1899.

MR. JAMES LINDOP, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting and of Council Meetings were read and confirmed.

The following gentleman was elected :—

ASSOCIATE—
Mr. JAMES GUEST, Stallman, Walsall Wood.

DISCUSSION ON DR. JOHN S. HALDANE AND MR. F. G. MEACHEM'S "OBSERVATIONS ON THE RELATION OF UNDERGROUND TEMPERATURE AND SPONTANEOUS FIRES IN THE COAL TO OXIDATION," ETC.*

Dr. HALDANE, in opening the discussion, showed samples of weathered coal illustrating the chemical theory put forward in the paper to account for the formation of black-damp, and liberation of heat in coal-mines.

The first sample consisted of the remains of a piece of coal which had lain in his laboratory for three years. It had been taken from the Bulhurst seam of North Staffordshire, which is wellknown as extremely subject to spontaneous fires. The lump had swollen and broken up into minute fragments, owing evidently to the formation of a white crystalline substance between the lamellæ of the coal. The white substance was strongly acid, possessed the astringent taste of iron salts, and gave the chemical reactions of a mixture of ferrous and ferric sulphates, along with free sulphuric acid. The crystals were undoubtedly the product of the oxidation of iron pyrites. Their bulkiness was largely due to the presence of water of crystallization, and of water in combination with free sulphuric acid. The black substance of the coal did not appear to be chemically changed by the weathering process, as the exposed angles of pure coal still seemed quite sharp and the surfaces bright. The disintegration of the coal would, of course, accelerate the oxidation-process by exposing more and more surface to the action of the air. In this sample, little or no carbonate of lime was present, so that the sulphuric acid was partly combined with iron and partly free. Presumably, therefore, no carbonic acid was liberated in the process of oxidation. It would be seen, however, that on bringing carbonate of lime into contact with a solution of the crystals, carbonic acid was evolved, while a brownish-yellow precipitate of hydrated ferric oxide was at the same time formed.

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* *Trans. Inst. M.E.*, 1898, vol. xvi., pages 457 and 495.

The second sample, a piece of coal which had lain outside for about a year, showed calcite-lamellæ, which had become yellow or brown in the process of weathering. These lamellæ consisted of a mixture of carbonate of lime, sulphate of lime and ferric oxide, the latter having evidently been precipitated from iron sulphate formed by the oxidation of iron pyrites. Carbonic acid would, of course, be liberated at the same time, and sulphate of lime formed. The process which had occurred in this sample was the whole of that represented by the two equations given in the paper, and the black-damp formed would be of the most common type, containing about 12·5 per cent. of carbonic acid, and 87·5 per cent. of nitrogen.

The third sample was from Foxdale lead-mine, and showed the weathering of both iron pyrites and spathic iron-ore (carbonate of iron). It would be seen that the pyrites was partly converted into crystals of iron sulphate, and the spathic ore to ferric oxide.

Mr. F. G. **Meachem** remarked that Dr. Haldane had pointed out the fact that the oxidation of the pyrites produced sulphuric acid, and while the process was going on, carbonic acid was liberated.

Mr. Alexander Smith said that there were eminent mining-engineers who held that the iron-pyrites theory was exploded, and had "gone into thin air years and years ago." He, therefore, wished to ask Dr. Haldane whether his chemical researches had quite satisfied him that his results were conclusive: in other words, that his theory was the only one by which the special conditions favourable to spontaneous combustion in coal could be set up. This was, of course, apart from the grinding or pressure of superincumbent rocks, which must be a considerable factor in producing such conditions.

Mr. W. J. **Hayward** observed that they had in South Staffordshire seams containing as much iron pyrites as any other seams in the country. It had not been his experience that these mines—containing a great amount of iron pyrites—were more subject to fire than those which contained comparatively little. In some seams, iron pyrites was present only in small quantities, but they were quite as liable to gob-fires as where iron pyrites existed in large quantities.

Dr. **Haldane**, in reply, said there was no doubt of the fact that the tendency to heating did not depend upon the amount of pyrites. Dr. Percy gave a number of cases, and they showed very clearly that the tendency to spontaneous combustion did not vary with the percentage of pyrites. It was not merely a question of the amount of pyrites, but also of the area of surface of pyrites exposed to the air. A thick mass of pyrites would not heat more rapidly than a thin layer. As regarded the chief question, whether iron pyrites was the only source of oxidation, he would not like to put forward any dogmatic statement. He thought, however, that the members had all the evidence on that subject before them. There was no doubt as to the formation of the crystals ; and it could not be disputed that these crystals were the product of the oxidation of iron pyrites. He held that the iron-pyrites theory rested upon a basis of definitely ascertained fact, and he would adhere to it until something else had been proved to go on in the coal besides the oxidation of pyrites.

Mr. **Isaac Meachem** wished to know whether the observations of Mr. F. G. Meachem agreed with those he had made since he read the paper. He found that the majority of fires occurred in the Thick coal-seam and in the softer and pliable parts. Iron pyrites was more evenly distributed, and in finer qualities, in those softer seams than in the other parts. Where pyrites was in greater bulk, and not so evenly distributed, oxidation did not take place so readily, the coal was not disintegrated, and, therefore, heat was not given up to the same extent. The amount of iron pyrites did not affect the proportion of fine coal so much as the distribution of it. It was evident too, that pyrites might be in a very fine state, and, therefore, more liable to cause fire.

Mr. F. G. **Meachem** concurred, and said that time was to be considered. The seams of coal to which Mr. Hayward referred, were all worked by longwall, and pits, in these cases, did not last more than 5 or 6 years. The face was always fresh and perfectly clear from the time they commenced. They might in such cases have all the conditions necessary for a fire, but the time was not sufficient. They started to sink at Hamstead collieries in 1875, coal was found, and the roads were driven in 1881. The workings extended from 1881 to 1898, and the place was like a slack-heap, owing to pressure and chemical action. The same thing occurred in the Bulhurst coal-seam, and the like trouble had occurred in Warwickshire collieries. Ten years elapsed before there was the least sign of fire at Hamstead colliery.

Mr. W. J. HAYWARD said that he had seen roads stand for double that length of time, without taking fire. He was referring to a coal-seam which contained a very large proportion of iron pyrites, where he had seen roads stand for 30 years, and he had never known a fire to occur either in the solid coal or in the gob.

On the motion of the PRESIDENT, seconded by Mr. CHARLTON, a hearty vote of thanks was accorded to the writers of the paper.

Mr. G. L. ADDENBROOKE addressed the members, as to his paper upon "The Midland Electric Corporation, Limited, and its Bearing on Mining in the South Staffordshire District," and was accorded a vote of thanks.

The meeting then terminated.

NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD AT THE NORTH STAFFORD HOTEL, STOKE-UPON-TRENT, MAY 8TH, 1899.

MR. R. H. COLE, IN THE CHAIR.

The minutes of the last General Meeting were confirmed.

The following gentlemen, having been previously nominated, were elected :—

MEMBERS—

Mr. **ARTHUR J. BURN**, The Waddle Patent Fan and Engineering Co., Llanelly, South Wales.
Mr. **WILLIAM FREAKLEY**, Consulting Engineer, 30, Harding Road, Hanley.
Mr. **WILLIAM HILL**, General Manager, Midland Coal, Coke and Iron Co., Apedale, Newcastle, Staffordshire.
Mr. **JOHN McGOWAN**, Engineer's Department, Corporation Waterworks, Nottingham.
Mr. **BENAIAH PARKER**, Colliery Manager, Foxfield Colliery Co., Limited, Blyth Bridge, Stoke-upon-Trent.

Mr. **BENAIAH PARKER** read the following "Notes on Coal-cutting Machinery in Use at Foxfield Colliery":—

NOTES ON COAL-CUTTING MACHINERY IN USE AT FOXFIELD COLLIERY.

By BENAIAH PARKER.

The direct motives for the introduction of coal-cutting machinery at Foxfield colliery were: (1) A larger output was anticipated from the same number of workmen, owing to scarcity of men in the neighbourhood; (2) decreased cost per ton; and (3) the attempt to obtain and maintain an increased output in view of the absenteeism of the men.

A large number of holing-machines have been constructed, amongst which may be mentioned the Winstanley, Gillot and Copley (disc or wheel), Bower and Blackburn (rotary bar), Ingersoll-Sergeant (percussive), Jeffrey and Hurd (bar). Many of these machines have been in use for some years in this and other countries. The Hurd machine was adopted by the directors of the Foxfield colliery, and has been used with fair success for the last 2 years.

It is not intended in this paper to enter into a comparison of the various machines now in the market, since what may be economical in one seam, with a good roof and other favourable conditions, may be both costly and dangerous under other circumstances. This paper simply describes the application of a machine to a particular seam, together with a few facts connected therewith, and it is hoped that it may prove of value to those who may be intending to introduce coal-cutting machinery into their mines.

The Hurd coal-cutting machine has been recently described by Mr. Thomas H. Barr in his paper on "Two Types of Electrical Coal-cutters."*

The dynamo is of the Crompton type, compound-wound, giving an output of 70 ampères at 450 volts, and sufficient power to drive two coal-cutting machines. The dynamo is belt-driven from a Browett and Lindley enclosed engine, running at 250 revolutions per minute. The combination is an excellent one, and the variation in voltage between full and no load is less than 3 per cent.

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* *Trans. Inst. M.E.*, 1899, vol. xvi., page 447.

The Woodhead coal-seam is the lowest-known seam in the Cheadle coal-field, and is said to be unlike any coal-seam found in the Potteries or in the district surrounding Cheadle. It lies at a depth of 754 feet from the surface, on the upthrow side of the large fault which divides the Foxfield and the Delph-house collieries. The method of working is on the ordinary longwall system with pack-gates, the line of face being half end and face, to enable the coal to be got down more easily and at the same time to deal with the slips frequently found in the roof. The seam may be said to be practically flat or nearly so, the dip or inclination being about 1 in 9.

The total thickness of coal is 2 feet 8 inches, and it is all saleable. There is about 7 inches of fire-clay, in which the machine holes; and this contains a thin pricking of softer material into which the men hole, when the holing is done by manual labour. The seam contains a large quantity of pyrites.

Two-thirds of the entire face-working is still holed by hand, and the remainder by machinery. When the machine was introduced it was placed upon a face 240 feet in length, and this was increased, in a straight line, to 450 feet. It was then thought desirable to increase the length of face cut by the machine from 450 to 3,000 feet; for this purpose two levels were driven, but upon one of the levels striking a downthrow fault, the face obtained was only 1,680 feet, and it is upon this face that the machine is at present cutting.

The reasons for obtaining so long a face for the machine were:—(1) To enable a day's output of coal to be holed and standing on the sprags while the men were sending out the other portion; (2) to enable the coal to "weight," and thus save blasting; (3) in case of the machine breaking down either mechanically or electrically, to have the necessary time for repairs without interfering with the output from the mine; and (4) a larger output for the same number of men would thus be obtained. Under these conditions the machine has been cutting since October, 1898.

The depth of cut made by the machine is 3½ feet on the average, and from 5 down to 2 inches in height. The machine, while cutting, is handled by 3 men, 1 man driving or regulating the feed, 1 man shovelling dirt from the sleeve of the bar, and 1 man setting sprags after the machine.

The machine is drawn along the face by means of a steel rope passing round a pulley-block placed 180 feet in advance, and attached at one end to the sleeve of the cutter-bar, and the other is wound round a small drum which is actuated by ratchet-gear worked by a crank.

The road for the machine consists of flat-bottomed rails, each 9 feet long, weighing 25 pounds per yard, laid upon special sleepers, which are spragged against the coal to prevent the machine from pulling the rails into the face. The pulley-block is attached to a post (which is fixed 180 feet in advance) by means of a chain.

Two rail-layers commence work a few hours before the machine-men, in order to lay down a suitable length of rails, so that the machine may continue to cut instead of waiting for rails to be laid. After the coal is cut, it is the custom to employ 2 men to follow after the machine and clear the holing-dirt into the goaf before the coal-hewers come in to work. Four men are employed in each gate, 2 men on each side, 1 man to get the coal down and attend to the packing and timbering, and another man to fill and tram out the coal.

It is usual to bring the coal down by blasting, and for this purpose, where shots are necessary, the holes are put in by machine-drills. The time occupied in fixing the drilling-machine is about 5 minutes.

Gates are set at intervals of 90 feet. Packs are built at the gate-ends extending 12 feet along the line of face, wastes are left 27 feet wide, and then another pack or chock is built. Props are set 2 feet apart, and 2 feet between the rows, only two rows of timber being set. The distance from the face to the front row of props is 4½ feet, and bars are set (where the roof is found bad) one end being let into the coal and a prop being placed under the other end.

The advantages obtained by the use of Hurd coal cutting machines will vary in different seams, and one amongst others will be either a reduction in the number of men employed for the same output, or a larger output will be obtained for the same number of workmen.

Mr. E. B. Wain enquired how far the coal-cutting machine was from the shaft, and whether any difficulty was experienced from the cables?

Mr. B. Parker, in reply to questions, said that a concentric cable was brought down from the pit-bank to the coal-cutting face. There had been heavy roof-falls upon the cable, but they had had no difficulty with it. The cable was slung down the shaft and caught at intervals—the shaft was wet. The cable had burst, and there was but little sparking. The pressure at the surface was 450 volts, and 440 volts at the coal-cutting machine. Occasionally they had sinking of the coal, but by spragging the coal properly they could clean out the holing.

Mr. R. H. COLE said that Mr. Parker had told the members that by the use of a coal-cutting machine he could get an increased amount of coal with the same number of workmen, or the same amount of coal with a reduced number of men. Could Mr. Parker give the production per workman per shift?

Mr. PARKER said he could not. Replying to further questions, he said that the usual stint for a holer varied greatly, and one machine practically performed the holing of 25 or 26 men. The machine cut to a depth of 3½ feet; with a longer bar it would cut 5½ feet; but the difficulty was to get the workmen to clear out the holing-dirt. It was better to have a 3½ feet than a 5½ feet cut. He thought that the Hurd machine would work efficiently with the face advancing to the rise in a steep mine—say 1 in 4. There was no difficulty in bolstering up on the dip-side of the rails, and the ordinary gob-timber would keep the rails from slipping. It took 15 to 20 minutes to change the cutters. The wear-and-tear of the cutters was an important consideration, and he advocated changing the cutters every 25 yards. There was about as much wear-and-tear of the cutters in the coal as in the warrant.

Mr. J. SETTLE asked whether there was any gas in the seam where the machine was worked, and if so, would there be danger in adopting an electrically-driven machine? It occurred to him that where gas was given off, electricity might be a source of danger.

Mr. B. PARKER said that the coal-seam in which the machine was used was not gaseous. The machine in use at Foxfield colliery would not be safe in a gaseous mine, but it could readily be made safe against gas.

The CHAIRMAN moved, and Mr. HAINES seconded, a motion that a vote of thanks be accorded to Mr. Parker for his paper.

Mr. W. FREAKLEY read the following paper on "The Application of Condensers to Winding-engines":—

THE APPLICATION OF CONDENSERS TO WINDING-ENGINES.

By WILLIAM FREAKLEY.

The primary object in applying a condenser to a winding-engine is to reduce the steam-consumption and consequently the cost of fuel. This entails a corresponding reduction in the quantity of water required for boiler-feeding purposes, and also in the wear-and-tear of the steam-generating plant, and this, again, reduces the cost of maintenance. In cases where the winding-engine is under its work, as often happens, the augmentation of the speed of winding is a great advantage.

There are several distinctive types of condensers, which may be classified as follows :—

(1) Condensers which are drained by air-pumps operated by the winding-engine, and in which the exhaust-steam is brought into direct collision with the condensing-water jet, the boiler feed-water being taken from the hot well.

At first sight, this would appear to be a simple and direct method of arriving at the desired result; but the drawbacks are, that it requires a certain amount of attention from the engineman for regulating the injection-water, etc., while at the same time it is very undesirable to increase the number of working-parts of the winding-engine or to interfere with its free running and handiness.

(2) Condensers which are drained by air-pumps operated by independent engines, either rotative or direct-acting, the steam being condensed by a jet, as in the previous case, and the boiler-feed taken from the hot well. This arrangement has much to commend it, owing to its independence of the motion of the winding-engine.

In practice, however, it has been found troublesome, owing to the difficulty of regulating the speed of the air-pump according to the varying quantity of condensing water to be delivered. This difficulty is especially marked when the pump is worked by a rotative engine, but with a direct-acting engine much less trouble is experienced.

(3) Condensers in which the air-pump is worked either by the main engine or by independent means, but in which the steam is condensed by cold-surface, or surface-condensers, and in which the condensing water is sometimes circulated through and sometimes around the tubes. This arrangement is suitable in cases where the hot-well water is unsuitable for boiler-feeding. It is, however, more expensive in first cost and maintenance than a simple injection-condenser.

(4) Ejector-condensers, having no air-pump, but in which the vacuum is maintained and the water of condensation delivered against the pressure of the atmosphere by reason of the high velocity attained in the combining or condensing-nozzles, the velocity being suitably reduced on leaving the outlet or delivery-orifice.

The drawbacks of this type of condenser, as compared with those just described, are that they, as a rule, require a much larger volume of water to condense a given weight of steam, and also that the vacuum available in the cylinders of the engines is not, generally speaking, as good as in an injection-condenser. Their extreme simplicity, however, goes a long way towards compensating for these disadvantages, and great improvements have recently been made in the construction of these condensers.

(5) Gravitation-condensers, in which the water of condensation is drained off by means of a descending leg or down pipe, the column of water in which is sufficiently high to balance the barometric pressure.

When a suitable fall of water is available, this arrangement has many advantages, and offers superior possibilities, owing to its simple and inexpensive construction, compared with other types. This condenser can be arranged so as to work without valves. The disadvantages of this arrangement are the height of fall necessary, and the space accordingly occupied.

(6) Gravitation-condensers, in which the water accumulating in the condensing chamber is caused to fall periodically into a small secondary condenser underneath the main one. The arrangement is such that when the water of condensation rises to a certain level in the main condenser, a vacuum is established in the lower chamber, when the water falls by gravitation into it. Air is then admitted which destroys the vacuum, and the water falls into the hot well or drain. This operation is repeated as often as desired, according to the quantity of water to be delivered.

This type of condenser, in the writer's opinion, has many excellent points, being eminently simple in construction. The arrangement of the valves is such as to reduce wear-and-tear to a minimum.

The movements of the working-parts are very slow (the valves acting every 5 to 10 minutes) without impairing the keenness of condensation, and maintaining a high and constant vacuum in the main condenser.

This condenser is capable of many modifications. When used as a simple injection-condenser the quantity of water required is no greater than is necessary in a modern jet-condensing engine. It may, however, be used as a surface-condenser in cases where the hot-well water is not suitable for boiler-feeding purposes.

(7) Evaporative condensers have been designed for use in cases where water is costly or scarce. They depend for their efficiency on the trickling of water in thin sheets, over the exterior surfaces of tubes, and the wellknown power of the consequent vapour of water to conduct away the heat and keep down the temperature. The water, thus heated, may be used, wholly or in part for boiler-feeding, the condensed water being drawn from the condenser by any suitable means. The arrangement may be called a vapour-surface condenser.

It is claimed for this arrangement that the total quantity of water, required for the condensation of the steam from a given engine is very little more than what is required for feeding the boilers generating steam to drive it.

Very little is known of the actual capability of this condenser to deal with large and varying volumes of steam, such as the exhaust from a winding-engine, but it would appear that the amount of surface required and space needed for a given condensing capacity must be very great as compared with other types of condensers, and the cost of construction must be heavy. One of the difficulties with this apparatus has been to obtain an uniform flow of surface-water over the tubes, a considerable portion of the aerial surface being practically negative.

It is to be hoped that the efforts of the various designers of this type may be successful, in view of the water-economy claimed.

(8) Air-surface condensers, in which the condensing surfaces are kept at a sufficiently low temperature, owing to the impingement of currents of air upon them. In some cases, fans have been used for producing the necessary air-currents, while in others the condenser has

been made in the form of a cage, and caused to revolve bodily in mid-air. Many practical defects and objections have arisen with both arrangements, and it may be safely urged that, from an economical point of view, the air-surface condenser is out of the run.

(9) And lastly, there is the blow-through condenser. The principal charm of this apparatus is its absurdly simple construction. The author believed that it was used originally in the atmospheric engines of Newcomen & Smeaton, and, consequently, was a very old invention. He had long thought, however, that the arrangement might be used with advantage on a large intermittent winding-engine when suitably modified, but this is a question for future development.

In view of the recently manifested desire on the part of progressive mining-engineers to avail themselves of simple and reliable means for effecting economy in the working of winding and other engines, the writer has thought it advisable to thus pass in review the several types of condensing apparatus, believing that there is an immediate future for their application. The object of the present short paper is to deal with the subject in a general way, in order that it may form a stepping-stone to the exhaustive discussion of a matter of much importance.

The writer has purposely left out the question of feed-water heating, harbouring the intention of dealing therewith on another occasion. It will be obvious, however, that feed-water heaters may be combined in a variety of ways with the various types of condenser.

There is one matter, however, of the most vital importance which must not be overlooked—namely, that whatever is done in the way of improving winding-engines and machinery, it should be of the simplest possible nature, all complicated or intricate devices being rigorously barred. There are many instances to be found, where the attempt to attain some theoretical refinement has had the result of saddling the plant with serious expense and disability. The writer hopes that the foregoing remarks may have the effect of causing those well able to deal with the subject to come forward with their views and experiences.

Mr. J. R. HAINES moved, and Mr. STOREY seconded, a vote of thanks to Mr. Freakley for his paper.

CHESTERFIELD AND MIDLAND COUNTIES INSTITUTION OF ENGINEERS.

GENERAL MEETING,

HELD IN THE TOWN HALL, BURTON-UPON-TRENT, APRIL 8TH, 1899.

MR. W. D. HOLFORD, PRESIDENT, IN THE CHAIR.

The members, on arrival, were divided into two parties, one of which visited the steam-cooperage, brewery, maltings and hop-stores of Messrs. Bass, Ratcliff & Gretton, Limited. The second party visited the engineering works of Messrs. Thornewill & Warham.

Mr. H. R. HEWITT (Honorary Secretary) read a letter from Mrs. John Jackson, of Stubben Edge, acknowledging the vote of condolence passed on the death of Mr. John Jackson.

The election of the following gentlemen was announced :—

ASSOCIATE MEMBERS—

Mr. SYDNEY RICHARD MALSON, Sheffield Road, Chesterfield.
Mr. WILLIAM ALBERT MALSON, Sheffield Road, Chesterfield.

ELECTION OF SECRETARY.

The balloting-papers for the election of a Secretary in succession to the late Mr. W. F. Howard were then handed to scrutineers, and at a later stage of the meeting, it was announced that Mr. G. A. Lewis had been duly elected.

The PRESIDENT moved that a vote of thanks be given to Mr. H. Richardson Hewitt, who had kindly acted as Honorary Secretary for some time.

Mr. R. **Thornewill** (Burton-upon-Trent) seconded the resolution, which was passed with acclamation.

Mr. **Hewitt** briefly responded.

Mr. H. R. **Hewitt** read the ballotting-list, prepared by the Council for the election of officers for the year 1899-1900; and also for the election of representatives of the Institution upon the council of The Institution of Mining Engineers for the year 1899-1900.

Mr. W. **Nowell** (Haunchwood Colliery, Nuneaton) read the following paper on an "Electric-power Plant at Haunchwood Colliery":—

ELECTRIC-POWER PLANT AT HAUNCHWOOD COLLIERY.

By W. NOWELL.

These notes on the electric-power plant at Haunchwood colliery have been written with the view of reopening a discussion on the subject of the best means of power-transmission in mines, and of obtaining the experience of other members in transmitting power required in collieries at a distance from the shafts.

The coal has to be hauled up an incline 5,100 feet long and a vertical rise of 480 feet, along a north level 3,600 feet, and a south level 3,000 feet (Figs. 1 and 2, Plate IV.). At *A*, 100 gallons of water per minute have to be raised, at *B*, 50 gallons per minute, and at *C*, 50 gallons per minute.

Previous to the adoption of electric transmission, the incline-rope and pump at *C* were driven by an endless plough-steel rope (1¼ inches in diameter) by an engine on the surface; the water at *A* and *B* was pumped by means of a Priestman oil-engine, or hauled in tanks up the incline; and the haulage on the level was worked by horses. The heavy working expenses and wear-and-tear of ropes, machinery and roads, made it impossible to work with any satisfactory result, and it was decided to erect an electric plant.

The generating-dynamo is rope-driven by a horizontal engine with two cylinders each 22 inches in diameter by 42 inches stroke, running at 70 revolutions per minute, and governed by Melling trip expansion-gear. There are 14 cotton driving-ropes, each 1¼ inches in diameter, coupling the engine to the dynamo.

The dynamo is compound-wound, running at 450 revolutions per minute, and giving 330 ampères at 500 volts. The bedplate is extended so as to carry a third bearing; the armature-shaft is made in two lengths, one part carrying the pulley, running in two bearings, and is fitted with a coupling-box, to which the shaft supporting the armature is bolted. This arrangement enables the armature to be removed without disturbing the driving-pulley or ropes. The bearings are adjustable, and each is continuously lubricated with an oil-ring, running in an oil-chamber. The dynamo is fixed on three slide-rails, with adjusting screws, so as to take up any slackness in the cotton-ropes, caused by stretching.

With the present full working-load, the engine indicates 180 horsepower, and the dynamo gives 120,000 watts or 159 electric horsepower, showing a loss of 21 horsepower. About 5 horsepower is lost in driving the engine and ropes, so that the efficiency is hardly 90 per cent.; but an allowance should be made, owing to the fact that the dynamo is not worked to its full capacity.

The switch-board consists of a polished slate base fitted into a strong wooden frame, and is fitted with:—an ampère-meter reading to 500 ampères; a Kelvin volt-meter reading to 1,000 volts; 2 double-pole main switches; 2 magnetic cut-outs; 17 way shunt regulating-switches; and resistance-coils.

The main cables consisted of 37/13 copper wires, insulated with vulcánized india-rubber, taped and served with layers of jute-yarn, and were carried in wooden casings down the downcast shaft to the main motor switch-board at the pit-bottom, a distance of about 750 feet. The cables to the haulage-motor on the levels and pump-motors at *A* and *B* had 19/17 copper wires, and were insulated in a similar manner; they were carried on earthenware insulators fixed to the timbering, and had coupling-boxes at 600 feet intervals, so that they could be removed when any extensive repairs had to be done to the road. The cables had a total length of 5,100 feet, and showed a loss of 50 volts.

The main haulage-motor for driving the incline-haulage is a continuous-current motor, running at 500 revolutions per minute, and giving 100 brake-horsepower with a current of 165 ampères at 490 volts (Figs. 3 and 4, Plate IV.). It is coupled to the gearing by 8 cotton ropes 1 inch in diameter. The average load is 120 ampères at 490 volts, but to overcome the inertia of starting the long length of rope and load it takes 180 ampères. To control this motor there is a 15 contact switch, 15 series of resistances to cut out, and 2 adjustable magnetic cut-outs, which are set to lift at 200 ampères: thus it is impossible to exert more than 130 brake-horsepower without altering the set of the magnetic cut-outs.

The haulage-motor for the levels is a continuous-current motor running at 500 revolutions per minute, which with 37 ampères at 450 volts gives 20 horsepower (Fig. 5, Plate IV.). It is coupled to the gearing by 5 ropes (1 inch in diameter). The average working-load is 30 ampères, but to overcome the inertia of starting it requires 50 ampères. This is regulated by means of a 9 way starting-switch and series of resistances to cut out, governed by a magnetic cut-out set to lift at 60 ampères.

The pump at *C* is a double-ram pump, 6 inches in diameter by 20 inches stroke, driven direct from a crank-shaft and pulley worked by the main haulage-rope. It delivers the water to the pump at *B*, which is an electrically-driven three-throw pump, with rams 5 inches in diameter by 8 inches stroke. The motor of 8 horsepower is coupled direct by gearing to the pump, and delivers the water to the shaft-sump through a wrought-iron pipe 4 inches in diameter.

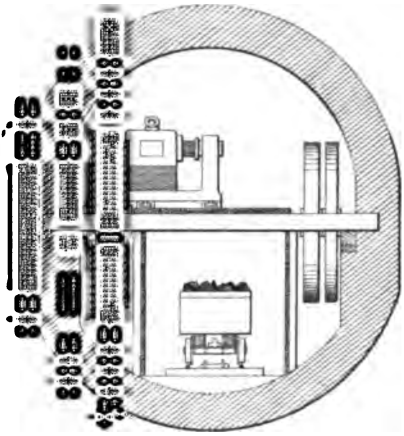
At *A* is a similar three-throw pump, with rams 5 inches in diameter by 9 inches stroke, and driven by an 8 horsepower motor by means of 4 cotton-ropes ⅞ inch in diameter. This pump delivers the water to the sump through a separate pipe. The average load on each motor is 16 ampères at 450 volts. There is not the customary difficulty in starting the pumps against the full head of water-column; and, as with the haulage motors, the inertia is overcome with 20 ampères. The motors are regulated and started by means of 5 way starting-switches and magnetic cut-outs.

The water from the sumps is raised to bank by a pumping-engine on the surface.

The underground landings, coupling-on places, and motor-houses are all lighted from the main cables. Surface-lighting is supplied from a separate plant giving 170 ampères at 100 volts.

Mr. G. Lewis (Derby) said he was afraid that he had had far too little experience of electric plant to discuss a paper of that character. So far as he could understand the problem, at Haunchwood colliery there were three feeders of water: passing down the incline from the shaft there was one at *A*, another at *B*, and a third at *C*. It was clearly very undesirable that the water should run to the bottom of the incline, and then have to be pumped to where it could be dealt with by the surface-engine. The arrangement, he could quite see, would be a very difficult one indeed to get over by means of ropes; and he was inclined to believe that Mr. Nowell had adopted a means of dealing with the water, which was an economical one. He suggested, however, that Mr. Nowell should give the members some idea as to the difference in cost of pumping the water by the old method and by his present arrangements, so that they could see whether any great saving had been effected. He was inclined to think, with the improvements effected in late years in electric plant, that electricity could be now applied to mining in a variety of ways not possible several years ago.

-20 Horsepower Motor.



End Elevation.

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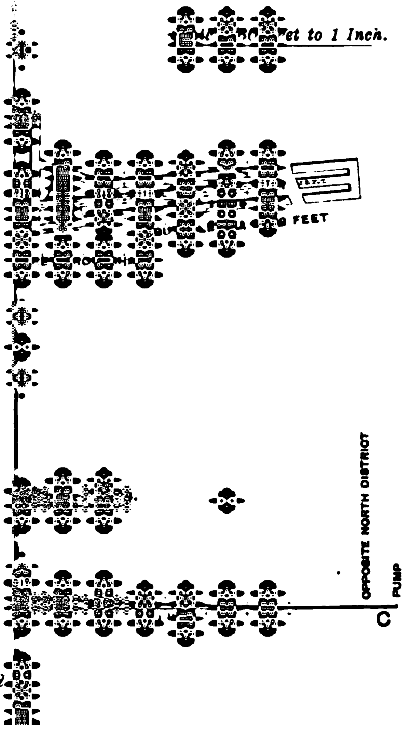

FEET
OPPOSITE NORTH DISTRICT
PUMP
C

Mr. J. A. LONGDEN (Stanton-by-Dale) observed that he had asked Mr. Piggford to give him particulars respecting the cable at Pleasley colliery.* The cable, which was similar to that described by Mr. Nowell, had been at work for about 7 years, but had now been taken out. The cable which Mr. Nowell described consisted "of 37/13 copper wires, insulated with vulcanized india-rubber, taped and served with layers of jute-yarn, and were carried in wooden casings down the downcast shaft to the main motor switch-board at the pit-bottom." Mr. Jno. Piggford wrote that "the new electric cables at Pleasley colliery are composed of 19 copper wires of No. 15 Birmingham wire-gauge, and have an insulating resistance of 300 megohms per mile. They are lead-covered, double-armoured, braided, and compounded, and hang openly in the shaft, being held in position by cast-iron clips, which are secured to the sides of the shaft by wrought-iron spikes driven into wooden plugs, for which holes were bored in the brickwork. The diameter of a wire of No. 15 Birmingham wire-gauge is 0·072 inch, the area 0·004071 square inch, and the weight per 100 yards is 4·68 lbs. The cost of this cable is 4s. 4½d. per yard, and therefore 100 yards cost £21 17s. 6d.; 2½ brackets per 100 yards at 12s. 6d. cost £1 11s. 3d., and the fixing of brackets and cable cost about £2 8s., making a total cost of £25 16s. 9d. per 100 yards. The Callender cable contains the same number and size of wire, is insulated with bitumen, and is protected by wooden casing. The cost of this cable is 1s. 9·43d. per yard; but as we require twice the length of Callender to concentric cable the figures for comparison are as follows:—200 yards of cable at 1s. 9·43d. cost £17 17s. 2d., wooden casing for 100 yards £7 2s. 6d., and fixing casing and cables £3, making a total cost of £27 19s. 8d. and showing a saving in favour of the use of concentric cable of £2 2s. 11d. The Callender, and more expensive cable of the two, had been taken out, having failed because the wooden casing had become saturated with moisture, and in consequence the insulation became soft and the cable was short-circuited. They had had 7 years' experience of their electric plant at Pleasley colliery, and he might state that during that time the pit had not stood for 3 days through faults in the electric plant. It had saved the cost of 60 horses—in fact, they could not have hauled the coal without it, as the pit was not laid out with due provision for mechanical haulage. There were five motors working underground, driven by two dynamos on the surface.

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* *Trans. Inst. M.E.*, 1897, vol. xii., page 633.

Mr. A. H. Stokes (H.M. Inspector of Mines, Derby) said that some time ago a large quantity of water broke in suddenly, and he believed that by means of the electric plant Mr. Nowell was able to cope with the water within a few hours, and so successfully that the pit went on working, whereas, had he been dependent upon ropes or compressed air, the pit would probably have had to stand for weeks. Such considerations might be matters of detail, but matters of detail were of great importance in managing a colliery. One point which appeared to him very important in all electrical machines was to have them powerful enough for the work that they were required to do. If an electric motor of 50 horsepower be required to do a certain amount of work, he would recommend the manager to ask his electrician to supply a motor of 100 nominal horsepower. When a machine was put down for just what was believed needful, it was often found that the inertia to be overcome in starting required more power than was anticipated or could be got from the motor, and therefore the safest way was to have an excess of power. The great secret of electric engines was to have at command double the power that they actually wanted in ordinary work.

Mr. H. Walters (Birley collieries) said that 14 years ago he had hung an electric cable down a shaft, inside a tube which was filled with hot pitch. It was now used in connexion with a telephone. One of the tubes was eaten through with water several years ago, and on examination he found that the cable was as good as when it was put in. The electric light had been put down their new pit, and with lead-coated armoured cables, short circuiting and burning through occurred in places. The armoured cable was taken out, and another cable substituted, and that was suspended in a tube in the shaft, and at intervals of 45 feet there was a socket where hot pitch was run in to carry the cable. This cable was inserted about 4 years ago, and it was still in use.

Mr. W. Nowell, replying to the discussion, said that he could not answer Mr. Lewis as to the question of cost. The electric haulage had saved the cost of 20 horses and 7 men. The cables had been in use for about two years, and there had been no trouble with them : they fitted tightly in the wooden box, and although the shaft was wet the management had succeeded, by making each joint with a mouth to cast the water outwards, and by other devices, in keeping the cable fairly dry. The cost of the cables was £500. Difficulty at first had been experienced in obtaining incandescent lamps which would stand a pressure of 500 volts. Ediswan lamps, guaranteed to carry 250 volts, had been used in pairs, but they were not satisfactory, as they could not stand the current. Instead, however, of putting two of these incandescent lamps in series, they now put three, and the lamps stood fairly well. The pit-bottom, landing-stages, motor-houses, coupling-on places, etc., were now lighted from the power-main, and in all about 50 lamps were in use. On the occasion of the influx of water, one armature was burnt out by forcing the dynamo—built for 8 horsepower—to develop 12 horsepower continuously. The outburst of water broke in at *B*, but in 4 days another motor and pump were at work, and dealt with the water successfully. He did not know of any other system by which they could have got to work so quickly. In erecting plant, power should be provided in excess of requirements, and it would then give them little trouble. The magnetic cut-outs were set for 130 horse-power, and with the slightest excess the current was cut out in a moment, and the machine was standing. A fuze took a few moments to take effect, and in that short time a haulage-rope might become overstrained, with the result that it would afterwards always be more liable to give way. The cables had been in use long enough to give them trouble if anything were going to occur, but he did not think that any difficulty was now likely to arise. Under the old system, a rope which cost £600 to £700 only lasted for 12 months, whereas the present rope had been in use nearly 3 years, and would last much longer. The conversion from the old system of surface-driving to a system of electric-haulage in the pit cost about £3,200.

On the motion of the PRESIDENT, seconded by Mr. G. LEWIS, a vote of thanks was passed to Mr. Nowell, and the further discussion of his paper was adjourned.

DISCUSSION OF MR. J. A. LONGDEN'S PAPER ON "COLLIERY-CONSUMPTION."*

Mr. SEBASTIAN SMITH (Shipley collieries) said that he had found great economy from using forced draught, which had enabled him to burn otherwise valueless fuel. In fact, he had used no other fuel for some years past.

Mr. GEORGE LEWIS (Derby) remarked that the question of colliery-consumption was not so much a question of fuel as of boilers. He thought that the members had all arrived at the conclusion that if they substituted for an old-fashioned egg-ended boiler (30 feet long by 5 feet diameter) a boiler (30 feet long by 8 feet diameter) with two flues, the amount of steam generated by the same quantity of fuel would be very much greater in the latter case than in the former. There was always at a colliery a certain amount of fuel which was of little commercial value; and he thought that the old-fashioned system of saving 6d. in the way of fuel and spending 1s. 6d. in the way of labour was coming to an end. He had proved that it was false economy to burn refuse under the boilers at a very small price, and to spend twice the amount of money on labour to enable it to be done; in fact it was more economical to tip it over the earth-bank.

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* *Trans. Inst. M.E.*, 1898, vol. xvi., page 366.

Mr. G. E. **Coke** (Nottingham) observed that, in addition to economy in raising steam, there were other economies which could be practised in using it which were not sufficiently considered. At Bestwood colliery, the Koepe system of winding was adopted in the upcast shaft, but it had now been removed. A few days ago, a gentleman having considerable experience at collieries in Germany expressed surprise that the system was not better known in Great Britain. This was certainly a matter which affected colliery-consumption, as the work of the winding-engine was much reduced by its use.

Mr. H. **Walters** said that Mr. Longden gave the depth of the shaft, but that would not indicate the depth from which the coal had to be hauled. At the Birley collieries, all the coal was hauled from the dip; and at the new pit, about 1,500 tons a day was drawn up a shaft 750 feet deep, but to get the coal to the shaft it was hauled about 5,400 feet up a rise of 1 in 12. At present, the colliery-consumption was only 3½ per cent.—smudge passed through a ¼ inch mesh.

Mr. A. **Davies** (Burton-on-Trent) said that at a colliery in Derbyshire the engine driving a Guibal fan used to consume 19 waggons of slack-coal per day. The cylinders were bored, and a new piston fitted, and the consumption was at once reduced from 19 to 10 waggons of slack-coal per day. The engine was afterwards fitted with expansion-valves, and the consumption was reduced 2 or 3 trucks further. His experience in submitting tenders was that mining-engineers were ready to adopt expensive plant, so long as it was economical. At the present time, his firm was tendering for a very large compound winding-engine, with an ordinary horizontal cylinder used in conjunction with a high-pressure vertical cylinder, and by that means, having two points instead of one, they would be able to start the winding much more quickly, a consideration of great importance in the output of a colliery. A recent strike of enginemen had shown mining engineers, that although they were able to obtain substitutes, the substitutes, owing to a difficulty in handling the engines, could not wind the same amount of coal within 15 or 20 per cent. The result was that owners were adopting appliances which would simplify the work of the engineman, comprizing steam reversing-gear, vertical and horizontal engines combined, together with a conical arrangement of the drum starting with, say, a diameter of 11 feet, and running in two revolutions up to 22 feet, and, of course, other drums would be in proportion. He was convinced that, in the near future, compound winding-engines would be generally used, the speed of winding would certainly be increased, and that would necessarily increase the output of the colliery.

Mr. G. W. **Dickinson** said that during the last 6 months of last year they often fell short of steam, and the engines had to be stopped until steam was raised to a sufficiently high pressure. He looked into the matter and came to the conclusion that the area of the flue between the boilers and the chimney was too small. He decided to apply forced draught upon two new boilers (30 feet long by 8 feet in diameter), but without any appreciable result. During the Christmas holidays, he built a new flue in addition to the other, and they could now maintain the steam-pressure with the greatest ease ; but it had the additional effect of increasing the colliery-consumption by 25 per cent. They were doing just the same work, and he could not discover the cause of that great increase.

Mr. A. H. **Stokes** said that the question of increased speed of winding was interesting, and especially to gentlemen like Mr. Sebastian Smith, whose apparatus recently prevented an overwound cage from falling down the shaft. A short time ago, he (Mr. Stokes) endeavoured to test the speed of winding at a particular colliery, and he made a chart of his observations which was published in his annual report for 1894. These members who had the chart would see that near the middle of the shaft one cage was descending at nearly a falling velocity, and the cage could not go faster than that. In raising coal, it must be remembered that at least the weight of the coal itself must be raised. The Koepe system had been tried, but it was not successful. If, however, a balance-rope were used they might reap an advantage, for with such a balance there would be nothing to lift but the coal, and we cannot get beyond that. With regard to Mr. Dickinson's increase of 25 per cent. in consumption of fuel, he should suggest that the heat was going up the chimney. Care should be taken as to the admission of air to the fires; there might be too much air, and there was a point at which there was too little—what they wanted was sufficient air to ensure perfect combustion. It might be asked how many colliery-managers indicated their engines. Cotton-mill engineers indicated the engines periodically, and if colliery-managers attended to such matters they would probably reduce the colliery-consumption.

Mr. G. E. **Coke** asked whether Mr. Stokes could say why the Koepe system was taken out at Bestwood colliery.

Mr. A. H. **Stokes** said that in the Koepe system the winding-drum was about 12 inches wide, and the rope went half round in a wooden ring grooved with a V track for the rope; besides this, there was a balance-rope passing from cage to cage, the whole being very similar to an endless rope. When the weight was taken off, the rope slipped and threw things out of gear. The slipping of the rope backwards and forwards appeared to give so much trouble that an ordinary drum was substituted, but they retained the balance-rope, which secured practically the same results without the drawbacks of the narrow drum.

Mr. J. A. **Longden**, replying to the discussion, said that Mr. Sebastian Smith used the fan draught and had confidence in it, as he found that for burning dust it was an excellent arrangement. Mr. George Lewis preferred to burn good coal, so did they all, but unfortunately when they had material sent out of the pit which they could not sell, they were compelled to burn it. They could not tip it over the spoil-bank, as it was sure to take fire sooner or later, and the best way was to burn it under the boilers and make as little smoke as possible. Some time ago he took steps for measuring the amount of air going into every flue of the 60 boilers at the collieries under his charge, and the variations were astonishing. Of course it showed that some of the flues had not been properly cleaned out, and that in other cases the bricklayer was wanted. There was four times as much draught in some flues as in others. The great drawback to the use of coal-dust for firing purposes was that it was carried along, and choked up the tubes much more quickly than if they used better coal. When he made the table, published in his paper, with the different percentages of coal consumed, and was trying to reconcile the colliery-consumption at the various collieries, he put these notes together, which he hoped might be of service to the members.

On the motion of the PRESIDENT, seconded by Mr. H. R. HEWITT, a vote of thanks was passed to Mr. Longden for his paper, and that gentleman briefly acknowledged the same.

DISCUSSION ON MR. G. C. ALLSEBROOK'S PAPER ON "COAL-CUTTING BY MACHINERY."*

Mr. **HENRY DAVIS** (Derby) wrote that in one particular he must differ from Mr. Allsebrook and the gentleman he quoted, namely, Mr. Clarke, on the subject of suitable cables for coal-cutting machinery, who stated that "the electric current should always be conducted in separate, as distinct from concentric, cables." † Quoting Mr. Clarke, he says that, "although concentric cables are less trouble to put up and cost some 15 per cent. less than separate cables, yet the latter are preferable for the following reasons," which reasons he (Mr. Davis) thought of sufficient importance to repeat:—"(1) A short circuit is almost impossible, as the cables of opposite polarity can be kept any desired distance apart. (2) Single cables are rapidly spliced and extended, and in the case of severe abrasion, reinsulated; in many cases it would be impossible to repair concentric cable, and it would need to be returned to the cable-maker, causing thereby great expense and inconvenience." Concentric cables are employed extensively and successfully for coal-cutting machinery, with the advantage that should a fall of roof occur, the flame, which is consequent upon the severing of a live cable, is minimized; the crushing of a concentric cable will connect the two conductors, so that the nearest fuze is immediately blown with a minimum of sparking at the point of fracture. Where two distinct cables are employed, a flame inevitably follows the breaking of a cable. Another practical advantage is secured by employing concentric cables, inasmuch as should there be a faulty place there is an immediate breakdown in the cable and the nearest fuze is blown. On the other hand, with two separate cables, leakage may and will occur (particularly in a wet pit) and goes on increasing, causing a considerable loss of current and inefficiency at the motor. Referring to Mr. Clarke's preference for separate to concentric cables—as the former are readily spliced and extended—he might say that this gentleman may not be aware with what ease concentric cables can be joined up by the employment of a junction-box—a most simple and effective device—the defective cable being cut out and the two ends connected to the junction-box. This plan is now growing in favour, it only takes a short time to connect the concentric cable up to the junction-box, and where a smaller cable is branched, a junction-box is employed to accommodate the varying diameters. Cast-iron boxes (which are damp-and-gas proof) are also employed for protecting switches and fuzes. It may not be out of place here to remark that concentric and armoured cables are found to be suitable and lasting for shaft work, however damp. They are preferably contained in galvanized iron piping, sufficiently large to contain the cable. This pipe is screwed into support-boxes at intervals in the shaft, depending on the weight and size of the cable and the depth of the shaft. Should any fault occur, it was only necessary to take out from the shaft the damaged portion, which could be replaced rapidly.

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* *Trans. Inst. M.E.*, 1898, vol. xvi., page 67. † *Ibid.*, page 72.

The noise made by the exhaust-air at the motor in an air-driven coal-cutter is a disadvantage and danger in the employment of air as the motive power in any mine. A properly constructed electrically-driven coal-cutter, where the gearing runs in oil, and the usual protecting plate over the machine is bolted down, makes so slight a noise that the working of the roof can be heard. He would like to add to Mr. Allsebrook's description of the Jeffrey electric longwall-machine that in addition to the arrangement for varying the speed of cutting while the machine was running, there was also a device for tilting the cutter-wheel; and the man in charge had two handles, namely, one for regulating the speed and the other for guiding the wheel so as to avoid pyrites or other obstructions. These two arrangements were found to be of practical utility, as they enabled the operator to control the machine with ease and precision.*

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* *Trans. Inst. M.E.*, 1898, vol. xvi., page 81.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

Held in the Wood Memorial Hall, Newcastle-upon-Tyne, June 10th, 1899.

Mr. J. B. SIMPSON, Past-President, in the Chair.

The **Secretary** read the minutes of the last General Meeting, and reported the proceedings of the Council at their meetings on May 20th and that day, and of the Council of The Institution of Mining Engineers.

The **Secretary** read the Balloting List for the election of officers for the year 1899-1900.

DEATH OF MR. A. M. POTTER.

The **Chairman** (Mr. J. B. Simpson) said that he had the melancholy duty of asking the members to pass a vote of condolence with Mrs. Potter on the death of her husband, who had passed away since the last meeting of the Institute. He felt sure that all of them who knew him would very much regret his loss.

SYLLABUS OF THREE YEARS' COURSE OF LECTURES FOR COLLIERY-ENGINEERS.

The **Chairman**, in drawing the attention of members to the syllabus of the course of instruction at the Durham College of Science for colliery-engineers, remarked that the requirements of coal-mining nowadays were of a highly scientific character, and it was absolutely necessary that the colliery-engineer of the future should have the knowledge to be attained by a scientific education. He hoped that engineers, and especially young engineers and others, would take advantage of this important course of lectures.

The following gentlemen were elected, having been previously nominated :—

MEMBERS—

Mr. **EDWIN STANLEY CLARK**, Colliery Proprietor, Oak Alyn, Cefn-y-bedd, near Wrexham.

Mr. **THOMAS PARKER**, Colliery Manager, Wellington Pit, Whitehaven.

Mr. **JOHN WALTER PEARSE**, Technical Translator, 1, Avenue Pescatore, Luxembourg-Ville.

Mr. **FRANCIS HOLBORROW GLYNN PRICE**, Mining Engineer and Estate Agent, Longlands Place, Swansea.

Mr. **GEORGE ROBINSON**, Colliery Manager, Harton House, Harton Colliery, South Shields.

Mr. **WILLIAM SMYTH**, Director of Mines, Gympie, Queensland, Australia.

Mr. **ARTHUR P. WILSON**, Mining Engineer, 11, Queen Victoria Street, London, E.C.

ASSOCIATE MEMBERS—

Mr. **JOHN FAIRLESS**, Mineral Manager, North Eastern Railway, Newcastle-upon-Tyne.

Mr. **JAMES M. GUMMERSON**, 9, Albury Park Road, Tynemouth.

Mr. **COLIN OCHILTREE MACDONALD**, Gowrie and Black House Collieries, Limited, Port Morien, Cape Breton, Nova Scotia, Canada.

Mr. **DOUGLAS STUART-SPENS STEUART**, 51, St. Ermin's Mansions, Westminster, London, S.W.; and P.O. Box 154, Pretoria, South African Republic.

Mr. **OSWALD THOMPSON**, Hendon Lodge, Sunderland.

STUDENTS—

Mr. **ROBERT WILLIAM GLASS**, Mining Student, Axwell Park Colliery, Swalwell, R.S.O., Co. Durham.

Mr. **THOMAS EASTON RUTHERFORD**, Mining Student, South Derwent Colliery, Annfield Plain, R.S.O., Co. Durham.

The following paper by Mr. D. Murgue on "The Murgue Recording Volumetric Anemometer" was read as follows :—

THE MURGUE RECORDING VOLUMETRIC ANEMOMETER.*

By D. MURGUE.

The regulations regarding fiery mines, enforced in the collieries of the Département de la Loire, France, since September 1st, 1895, have compelled mining engineers to provide ventilators with a speed-recording apparatus and with an automatic pressure-gauge for recording depression or compression.

It is easy to follow the train of thought which led up to this enactment: each apparatus, taken by itself, furnishes only an incomplete record, but the two check one another, and the comparison of the diagrams traced out by them enables the observer to decide, for instance, whether a given depression is due to an acceleration in the speed of the ventilator or to an accidental constriction of the underground airways.

Nevertheless these two records do not give the mining engineer that piece of information which is for him the most interesting of any, namely, the volume or the number of cubic feet of air passing through the workings in a given time. Imagine for a moment that the return-airway is suddenly blocked by a fall of rock: the speed-recorder will still continue to record the speed, and what is more, a constant speed (if the engine be provided with an automatic cut-off gear), the pressure-gauge will go on recording a depression differing but little from the customary average – and yet not a cubic foot of air will be passing through the workings.

Bearing this fact in mind, and guided by the writer's former researches, he had endeavoured to construct a recording volumetric gauge such as would of itself suffice to take the place of the two gauges prescribed by regulation. The state inspectors of mines had been good enough to approve of this method of attacking the problem—that is, taking the ventilation as the fundamental datum ; and with the help of his colleagues of the Compagnie de Montrambert, he had succeeded in producing the apparatus, a type of which was now before the members, which had been at work for 2 years in connexion with five mine-ventilators.

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* Translated by Mr. L. L. Belinfante, M.Sc.

The instrument which really measures the intensity of the air-flow, if he might so express himself, is the Pitot tube, wellknown to all, and itself the subject of a highly interesting paper by Mr. Rateau.* Before describing, however, the particular arrangements which he had adopted, he thought it well to set forth certain principles but dimly apprehended by many of his colleagues, principles with which he had only recently become acquainted.

In order to appreciate thoroughly the effect of a ventilator exhausting air from the mine which it ventilates, we must imagine it preceded by a vast chamber into which the air coming from the mine expands and remains stationary for a time before rushing into the inlet of the fan (Fig. 1, Plate V.). In this chamber prevails a certain pressure H, necessarily lower than the atmospheric pressure. The difference revealed by the water-gauge is what mining engineers are accustomed to term the depression. The writer calls this pressure H the static pressure, so as to emphasize the fact that here we are concerned with air that has no speed.

In practice, the supposed chamber exists but rarely. In most cases the air, exhausted from the mine, travels direct to the ventilator by an airway of moderate cross-section wherein the air maintains a high speed (Fig. 2, Plate V.). Now, the pressure H′ which prevails in such an airway is no longer the static pressure. The former is inferior to the latter, in virtue of the Bernouilli theorem, by the quantity $\frac{v^2}{2g}$.

$$H' = H - \frac{v^2}{2g},$$

v being the velocity of the air at the point, where the depression is measured by the tube *a*.

But, if we wish to determine the true static pressure—and to this point the writer desired to direct the earnest attention of mining engineers—it will suffice to curve the above-mentioned tube into the form of a Pitot tube facing the current. The shock-pressure $+ \frac{v^2}{2g}$ destroys the negative term $- \frac{v^2}{2g}$, and we have finally on the water or mercury of the manometer, the statical pressure H, that is

$$H - \frac{v^2}{2g} + \frac{v^2}{2g} = H.$$

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* *Trans. Inst. M.E.*, 1899, vol. xvii., page 124.

That such is the fact the following experiment, which the writer had performed over and over again, will show (Fig. 1, Plate V.). Place a Pitot tube *b* in the constriction which precedes the inlet of a Rateau ventilator, and a straight tube *a* in the wide part of the air-drift, where the speed of the air is comparatively very low, the differential gauge with which both tubes communicate will be found to record an equality of pressures.* Without being considered guilty of too great presumption the writer may, therefore, lay down the following proposition:—The Pitot tube, so arranged as to face the current, transmits the static pressure. As a corollary, he may be allowed to answer a question which is often put:—How should the orifice of a tube be arranged which is intended to transmit to a pressure-gauge above bank the pressure prevailing in an airway? The static pressure being alone that which possesses any interest, the orifice must be placed facing the current. Let us return from this digression to the apparatus which forms the main subject of the present communication.

The foregoing pages have made it clearly apparent that if a straight tube *a* (Fig. 2, Plate V.) be fixed beside a Pitot tube *b*, in an air-way through which passes a current of considerable intensity, and if these two tubes be brought into communication with the two branches of a differential gauge, this gauge will indicate for the air-current that strikes the orifice of the straight tube the function of the speed $\frac{v^2}{2g}$. In point of fact this is an anemometric method which has been known for some time and is often used, as, for example, by the Prussian Fire-damp Commission.†

In order to utilize this arrangement for the measurement of air-volumes it would evidently be sufficient to place the orifice of the straight tube at that point of the cross-section where an average speed prevails, the volume being simply equivalent to the product of the area of the section multiplied by the speed. But even that is not necessary, as numerous experiments made by the writer at the Bessèges colliery had shown that when the average speed of a current in an airway is made to vary, the form of the curves of equal speed remains unchanged. Whence we may conclude that the speed at any point of the section bears a constant relation to the average speed.

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* This experiment has also been performed by Mr. Rateau under slightly different conditions, *Annales des Mines*, 1898, series 9, vol. xiii., page 335, and *Trans. Inst. M.E.*, 1899, vol. xvii., page 126.

† Mr. Rateau advises that the extremity of the straight tube should be furnished with a small screen *p* (Fig. 2, Plate V.), bevelled off on the side of the current, in order to prevent the eddy produced by the tube from disturbing the parallelism of the trajectories in front of the orifice.

It may then be affirmed that the change of level *h* of the differential gauge is in all cases a function simply proportional to the square of the volume :—

$$h = \mathrm{K}v^2.$$

As to the coefficient K, which sums up all the constant factors, section, density, etc.,* it will be sufficiently determined by means of a preliminary measurement carried out in the customary manner.

Such is the very simple principle upon which the recording volumetric gauge, herein described, has been based. Before proceeding to discuss its applications, however, mention must be made of one difficulty in particular which it was found necessary to overcome.

The speed which usually prevails in the return-airways being 800 to 1,000 feet per minute, the change of level *h* of the differential pressure-gauge, expressed in terms of a water-column, would not exceed 0·050 inch, a load which, although it might deflect a recording apparatus, would not suffice to give reliable readings. It was, therefore, indispensable to induce an acceleration of speed at one point in the gallery, which could only be done by narrowing or constricting the cross-section thereof.

Theoretically, this procedure is quite permissible for, if the gradual transition is properly arranged, to the rise and to the fall of pressure between the original cross-section and the constricted cross-section (dotted outline in Fig. 2, Plate V.), the *vis viva* produced during the period of acceleration is wholly restored during the period of slackening, and thus everything takes place as if there had been no constriction at all. It would appear that practical experience corroborates these theoretical assumptions. Nevertheless, in the absence of confirmatory experience it is hardly probable that we should have agreed to place such obstacles in the road of the ventilating-currents, being naturally reluctant to do anything which might weaken them.

It was, therefore, very satisfactory to meet with the desired constriction in the ventilators themselves. These are of the Rateau type : the air-admission canal at the inlet narrows gradually to a minimum of 1·68 of the diameter, and then widens out to connect with the spiral diffuser. At the narrowest point, a speed of 2,000 to 2,500 feet per minute prevails, corresponding in the differential pressure-gauge to water columns of 0·24 to 0·32 inch. These loads seemed to the writer quite sufficient to be self-recording, reliable, and capable of suitable amplification.

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* The density of the air is not absolutely a constant; but it varies within limits so narrow, that in practice it may be considered a constant.

Therefore the two measuring-tubes, the straight and the Pitot tube, were fixed permanently in the narrow portion, and then joined up by means of leaden piping* with the two branch-pipes of the differential pressure-gauge which remains to be described. As generally happens, the writer did not at the first attempt hit upon exactly the arrangement which is described to the members, and the original type of apparatus has now been discarded. Nevertheless it may be as well to describe in the first instance the original type, as it will help to explain the apparent complications of the later type.

The two branches of the pressure-gauge were represented by the unequal compartments of a rectangular zinc box or holder dipping into a cast-iron tank filled with water (Figs. 3 and 4, Plate V.). At the top of each compartment, two taps (*a* and *b*) communicated with the pipes coming from the measuring-tubes, the straight tube corresponding to the small compartment and the Pitot tube to the large one. A third tap allowed of communication between the two compartments, and it was therefore possible to equalize the pressures in them, an equalization which is indispensable from time to time, in order to test the zero of the instrument.

The small compartment was occupied, as now, by a cylindrical float, immersed up to its horizontal diameter. This float was connected to a long lever formed by a hollow tube, light and yet rigid, which ran along the bottom of the tank, and issued therefrom at its two ends: at the rear, it was joined to a shaft whose pointed extremities turned in two small screw supports, *s*, fixed to the tank, and at the forward end, it commanded, by means of a short crank *m*, the lever of a Richard recorder.

It will now be easy to understand how the apparatus works. Under the influence of the various pressures transmitted by the measuring-tubes the water rises in the small compartment, carrying the float with it. The water falls in the other, but proportionately less in consequence of the greater surface. It is advisable to extend this surface as much as possible, in order not to diminish too much the amplitude of movement of the float. The motion of the float is transmitted by levers, with suitable amplification, to the recording pen, which traces out on a diagram ordinates proportional to the square of the volume.

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* The pipes communicating with the gauge must be laid with a gradual rise, so as to avoid bends wherein condensed water might accumulate and block the passage.

But a very serious defect was soon discovered in this first type of apparatus. In the narrow channel *e*, which separated the zinc box or holder from the inside wall of the tank, the water remained subjected to atmospheric pressure, and fell there while it rose slightly within the holder. Now, given the same volume, that is, the same alteration of level within the two compartments, the position of the float was influenced by this unmeasured fall, and transmitted sensibly different readings according as the equivalent orifice of the mine was large or small, that is, according as the change of level in the channel *e*, equal to the depression, was more or less marked.*

With the view of avoiding this difficulty and yet of preserving the system of the pneumatic trough, the author modified slightly the shape of the compartments, making the larger one form a continuous jacket around the smaller one (Figs 5 and 6, Plate V.). Moreover, around and outside the tank a deep and narrow cast-iron trough has been placed, wherein the larger holder dips on all sides, while the smaller holder continues to dip into the inner tank.

The water in the outer trough alone is exposed to atmospheric pressure and is completely shut off from the water in the tank; therefore the disturbing action previously described ceases to take place, and in this respect no further fault can be found with the apparatus.

Unfortunately, however, this modification necessitates the introduction of some complications into the lever. It has been found necessary to give the lever some extraordinary bends, in order to enable it to issue from the tank and pass through the trough by its two ends without interfering with the hydraulic seal. As a matter of fact, however, not much harm is done thereby: the lever having only very light work to do, the necessary rigidity is ensured by strengthening the bends as shown in the drawings.

The recording-cylinder is duplicated by a reserve cylinder, which takes a strip of paper 3 feet long. This strip, unrolling at the rate of 0·20 inch per hour, lasts for a week, and is renewed every Monday. It is ruled with curvilinear ordinates plotted at one-hour distances, and with horizontal lines graduated in cubic metres, and arranged farther and farther apart according to the law of the squares of the volumes (Fig. 7, Plate V.).

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* To note only one point, the zero position lost all fixity. When pressure was equalized in the two compartments, the zero rose or fell at the same time as the depression. The new arrangement ensures absolute fixity of the zero, whatever may be the equivalent orifice of the mine or the speed of the ventilator.

As the writer has previously said, the ruling of the paper is done very simply by means of comparative measurements. The difference between the real volume of air and that given by the graduated strip is easily corrected by allowing the little sliding-sockets, *m* and *n*, at the ends of the connecting-link to run as far as may be necessary on the corresponding levers.

The checking, and, if necessary, the correction of the zero must be made, at least, every time that the paper-strip is changed.* A small funnel, *c*, going down nearly to the bottom of the tank (thus ensuring hermetical automatic closure), and a small waste-tap, *v*, allow of the necessary amount of water being added or removed, as desired, to bring back the instrument to the zero-point, if any deflection chances to have taken place.

Finally, the whole apparatus is enclosed within a glass case.

Such is, in its essential aspects, the apparatus which the writer has invented. He had laid upon himself the following conditions which appeared to him indispensable for the achievement of permanent success:—

1. To have at one's disposal more than sufficient motive-power, by making use of a float of large dimensions.

2. To reduce the passive resistances to a minimum, by restricting them to the friction of two points in two supports, which are easily lubricated.

3. To have everywhere a water seal or hydraulic closure, the only true hermetical closure.

4. To bring into play large masses of water and air, so as to diminish oscillation.

Save and excepting the last-named condition, the foregoing desiderata seem to the writer to have been fairly well achieved. The apparatus is extremely sensitive, and so soon as an artificial block is produced in the airways, the pen is seen to go down. If, on the other hand, a separation-door is opened, the pen rises immediately. The writer may remind members that the depression-recorder would have given inverse results.

If the ventilator be stopped, the pointer continues to mark the flow due to natural action alone, and in order to make sure that one is not labouring under some delusion it is sufficient to bring the instrument back to zero. The difference between the ordinates, however insignificant it may be, is plainly attributable to the mere effect of the circulation of air.*

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* It is a pity that the apparatus cannot be utilized for the measurement of the re-entering currents which are produced in warm weather. To do this, the measuring-tubes would have to be arranged differently.

But this very sensitiveness is the cause of a serious defect: the pointer is in a state of continuous oscillation, and as the speed of travel of the strip is perhaps too low, the result is that smudgy diagrams are sometimes produced.

The writer may say at once that better diagrams are produced in shafts used exclusively for ventilation than in those which serve both for that purpose and for sending timber, packing material, etc., down into the mine. It will be easily understood that the frequent opening of doors, however carefully closed, will cause much oscillation of the pen.

The writer endeavoured to meet this difficulty by interpolating, between the measuring-tubes and the apparatus, enclosed spaces of a cubical content of about 1·75 cubic feet, with the hope of deadening the oscillation, but the endeavour was not very successful.

It is possible, as someone remarked to the writer, that the measuring-tubes are placed too close to the inlet of the ventilator. If perhaps they were fixed further off in a constriction or narrow place arranged in the return-airway, diagrams of a less tumultuous character would be recorded. This is a supposition which the writer has not verified in practice.

It may be, too, that the oscillations are due to periodic displacement of slow or fast currents, oscillating around their mean position, in such wise that if a certain number of measuring-tubes were spread over the cross-section, a less oscillatory mean result would be recorded on the diagrams. This experiment would be worth making.

Perhaps, too, the diagrams would be better if the fan-engines were provided with good regulators, keeping up a constant speed. In practice, the regulators just keep the engine from running away in case of a belt slipping.

However that may be, the apparatus described in the foregoing pages, with all its imperfections, appears to the writer destined to furnish useful records to mining engineers.

Mr. J. B. SIMPSON moved a vote of thanks to Mr. Murgue for his paper describing an interesting appliance.

The resolution was cordially approved.

Mr. M. WALTON BROWN read the following description of the "Davey-Bickford-Smith Safety Shot-igniter":—

metric Anemometer."

Fig. 7.

April 17th 1899. Tuesday

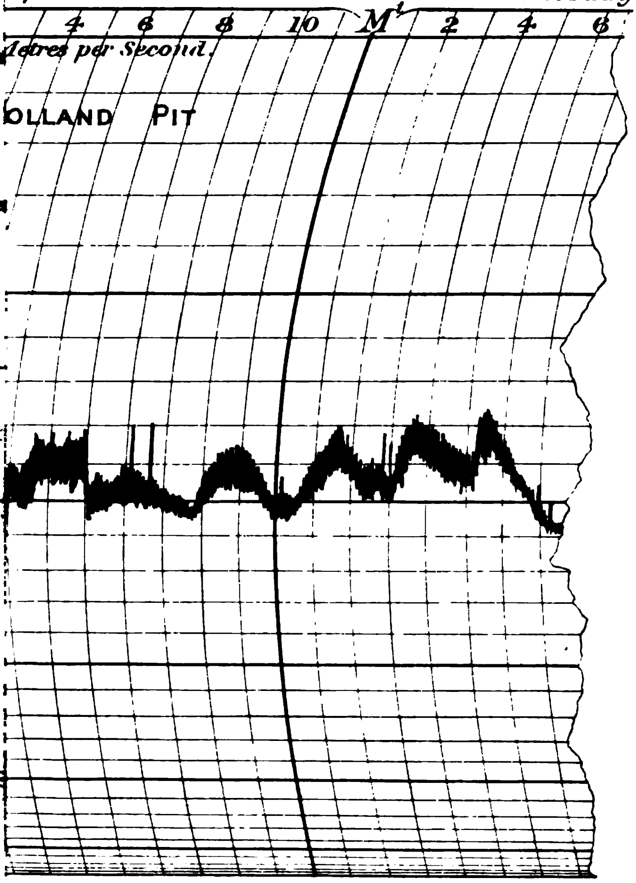
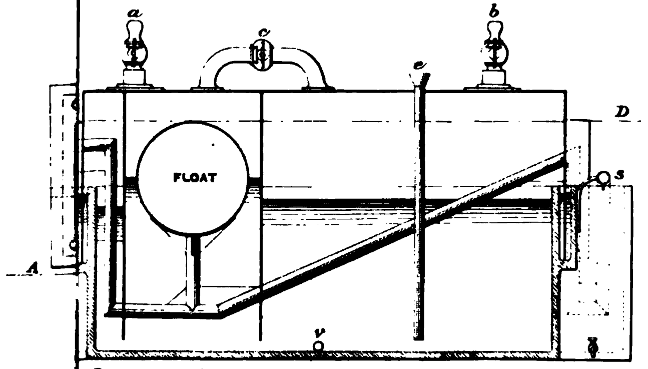


Fig. 6.


a
c
b
e
D
FLOAT
s
A
v

Section on Line A B of Fig. 5.

DAVEY-BICKFORD-SMITH SAFETY SHOT-IGNITER.*

I.—REPORT PRESENTED TO THE FRENCH FIRE-DAMP COMMISSION BY MR. G. CHESNEAU, CHIEF INSPECTOR OF MINES.

On December 10th, 1897, the Minister of Public Works forwarded to the French Fire-damp Commission for examination and report a new system of safety-igniter for firing shots in gaseous mines, which had been submitted by Messrs. Davey, Bickford, Smith & Co., manufacturers of dynamite and detonators at Rouen. Samples of these igniters and of the firing apparatus were submitted on December 11th by Mr. Harlé, engineer of the above company, who showed their mode of operation and handed them to the writer in order to carry out tests with them in explosive media.

It is wellknown that when a fuze is lit, a jet of hot gas is evolved during several seconds, accompanied by the projection of granules of powder in a state of ignition and capable of igniting fire-damp. Several arrangements have already been proposed in order to avoid this ignition by confining the gaseous products of the burning fuze either in an entirely enclosed space or within a safety-lamp, from which the fuze is only to be withdrawn when the combustion of the powder-core is advanced sufficiently to prevent the projection of any incandescent particles. This occurs after about 4 inches (10 centimetres) of fuze has been consumed.

A considerable number of appliances of this order used in coal-mines have been described in the *Annales des Mines*.† Some of these ignite the fuze by means of a percussion-cap (Lens shot-firing pistol), others by means of a safety-lamp (Johnson, Howatt and Petit safety-lamps); others, again, by making use of the heating of air by abrupt compression (Bourdoncle pneumatic igniter). With all of these different pieces of apparatus, it is always necessary to wait for some seconds before passing from one shot to the next, a fact that limits considerably the number of shots that can be fired at once, and entails the employment of fuzes of considerable length.

Messrs. Davey, Bickford, Smith & Co., of Rouen, have already attempted to avoid these objections by means of a chemical igniter.‡

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* *Annales des Mines*, 1898, ninth series, vol. xiv., page 567.

† "Note sur l'Allumage des Coups de Mine dans les Exploitations Grisouteuses (Note on Firing Shots in Fiery Mines)," by Mr. L. Janet, Inspector of Mines, *Annales des Mines*, 1892, ninth series, vol. i., page 351.

‡ *Ibid.*

A little glass bulb, containing sulphuric acid surrounded by a mixture of potassium chlorate and sugar, is placed in a copper tube, and the fire due to the heating produced on crushing the bulb by means of a special pincers, is communicated to the fuze attached to one end of this tube, while the gases escape by the other end, which is closed by means of discs of wire-gauze. This igniter, tried successfully in several coal-mines, had given numerous miss-fires in others. Among other objections, it was found to be rather too delicate to be placed in the hands of workmen, and the possibility of the tube splitting while the glass bulb was being crushed, also presented itself.

The new igniter devised by the same firm and submitted to the French Fire-damp Commission allows, as in the case of the last appliance, the fuze to be lit in a fiery atmosphere, and to be immediately left as soon as it has been lit, while it is much more simple to use, and avoids the danger of splitting the tube that encloses the igniter. This result is obtained by employing a special igniting-cap, which on a small scale resembles in construction a Davy safety-lamp. It is constructed as shown in the annexed sketch (Figs. 1 and 2), and consists of :—A fulminating-cap, A, into which is inserted a spiral, B, of brass wire, carrying a small quantity of powder. C is a brass tube into which the fuze is inserted as far as the constriction D. E is a gauze-tube of very fine brass wire having 1,089 meshes to the square centimetre, which prevents any direct contact between the heated products of combustion and the external atmosphere, just as in the case of the safety-lamp. It is firmly attached to the cap, A, at one end, and to the tube, C, at the other, uniting these two parts. The wire spiral, B, prevents the wire-gauze from being crushed in while the igniter is in use or is being transported. There is a longitudinal seam in the wire-gauze, which is closed by an overlap of about a semi-circumference.

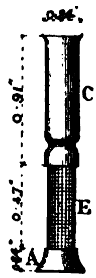

FIG. 1.

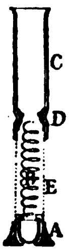

FIG. 2.

In order to fire the shot, the fuze is pushed as far as possible into the tube, C, its end being tightly pinched by means of a special tool, which is also employed for cutting the fuze to the required length. The igniter is then placed in a pistol which carries the igniter, fires the cap by percussion, and allows the igniter to be liberated very rapidly. With a little practice, it is possible thus to fire a series of shots in a few seconds. With this object the igniter is placed in the pistol, as shown by the sketch (Fig. 3). A groove, *a a*, takes half the thickness of the igniter, whilst a cover, G G, movable on a hinge, *b b*, and with a semi-cylindrical groove, b_1 b_1, holds the igniter in place when the cover is closed on its hinge until the projection H, with which it is furnished, is caught in the spring-catch, I. It is then sufficient to pull the trigger, K, of the pistol, to lift the hammer, L, which drops upon the cap and fires it. The tube, *c c*, allows the fumes to escape. The moment the cap has been fired, pressure on the button, M, frees the projection, H, and the lid or cover, G G, moved by an opposing spring not shown in the figure, rises automatically, thus allowing the igniter to be removed, and leaving the pistol in readiness for the firing of the next shot. In Fig. 3, the cover, G G, is shown lifted up.

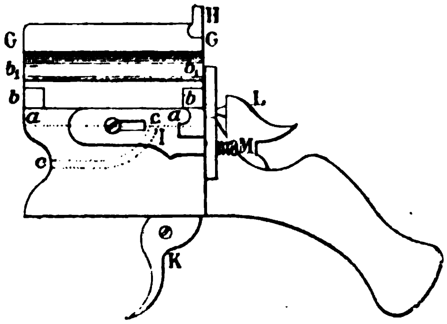

FIG. 3.

We have worked this apparatus in explosive mixtures at their highest degree of inflammability, consisting of mixtures either of air and marsh gas or of air and illuminating gas, employing the conditions which should be most favourable to the propagation of an explosion through the wire-gauze. In order to do this, we have fired the igniters attached to fuzes placed in an explosive current without replacing the cover or lid G, taking care to keep the igniter in its proper place. Under these conditions, we have not succeeded in causing ignition of the explosive mixture in 30 trials made with marsh gas and in 30 trials with illuminating gas.* It may, therefore, be admitted that the Davey-Bickford-Smith igniter presents a very high degree of safety.

At the moment when the fulminate explodes, the passage may be noted through the wire-gauze of a dull red light lasting for an exceedingly short time, but too rapid and already too far cooled to ignite an explosive mixture. Neither the combustion of the powder covering the wire spiral nor the spitting of the fuze project any incandescent particle through the wire-gauze.

It may be asked whether it would not be possible to replace the wire-gauze, E, by a plain metal tube sufficiently strong to withstand without bursting the compression of the products of combustion; which would evidently be a much simpler and less expensive construction than the wire-gauze cylinder; but although there is after all a very small quantity of explosive matter employed, its force would be sufficient to project the fuze from its place, even if the former were fairly well secured, seeing that the material of which the fuze is made is tolerably plastic. We have, in fact, found that if the fuze is not squeezed firmly into the tube, C, of the Davey-Bickford-Smith igniter, it is thrown out with a certain amount of violence, notwithstanding the passage of the products of combustion through the meshes of the gauze. In no case, however, has the fuze been detached from its place when it has been properly secured.

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* We had proved that the spitting of the ignited fuze, when unprotected, fired illuminating gas every time, but marsh gas very rarely. Experiments in the former mixture are therefore particularly conclusive. The fuze employed had been manufactured with especial care.

We may summarize the experiments which we have performed by saying that they have brought us to the conclusion that the safety-igniter of Davey, Bickford, Smith & Co. presents the very highest degree of safety; at the same time it allows shots to be rapidly fired, and, like several of the other forms of similar apparatus previously described in the *Annales des Mines*, it deserves to be brought to the attention of those engaged in working fiery mines.

II.—OPINION OF THE FIRE-DAMP COMMISSION.

The Commission has adopted the conclusions of this report, and gives the opinion that it is justified in proposing to the Minister of Public Works to insert Mr. Chesneau's report in the *Annales des Mines.*

Mr. M. WALTON BROWN said that the use of this pistol form of shot-firer had been approved by the French Government, and they had been in general use for about a year.

The CHAIRMAN (Mr. J. B. Simpson) said that this shot-firer seemed very simple, but no doubt would require further experiments before they were inclined to adopt it for use in British mines.

DISCUSSION ON MR. W. T. GOOLDEN'S PAPER ON "COAL-CUTTING BY MACHINERY.*

Mr. H. W. Appleby (Bradford) wrote that many colliery-engineers always desired to use armoured cables, but this, he thought, was quite unnecessary, and it certainly added very greatly to the cost. Where the cables are carried along main roads, the ordinary insulation is quite sufficient. At the working-face, where loose cable is lying about or dragged over the ground, he certainly thought that armoured or protected cable should be used.. If the mine is very damp or the cables have to pass through water, lead-covered cable would be necessary, as the leaden sheathing saves the insulation from rotting away. Cables, if slung from the roof, should not be stretched too tightly, but allowed to sag so that, if any part of the roof falls, the cable will not be broken, but will give way and allow the fallen part to drop clear of the cable. He had heard of several cases of this kind occurring recently in a mine. Where cables have been stretched tight, the fall of roof cuts through them, but in places where they were slung loosely, they simply came down with the roof and no damage was done to them.

It is most important where several electrically-driven machines are depending on one source of supply that this should not be interrupted, and it will easily be seen that the fixing of cables, so that the chance of fracture may be reduced to a minimum, is very necessary. In addition, the rupture of a cable carrying a current at high pressure generally causes a big flash, and this is a source of danger against which provision has to be made. He would like to make a few more remarks, but as he hoped to have the pleasure of submitting a paper bearing on this subject to the Institute at some future date, he would defer his remarks till then.

The following paper by Mr. H. G. Stokes on "The Ore-deposits of the Silver Spur Mine and Neighbourhood, Texas, Queensland," was read as follows :—

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* *Trans. Inst. M.E.*, vol. xv., page 378 ; and vol. xvii., page 221.

THE ORE-DEPOSITS OF THE SILVER SPUR MINE AND NEIGHBOURHOOD, TEXAS, QUEENSLAND.

BY H. G. STOKES.

INTRODUCTION.

Introductory.—In preparing these notes the writer has endeavoured to give a detailed account of the mode of occurrence of the ore-bodies at the Silver Spur, which have been constantly under his observation since they were first opened, in the hope that the information may be of use as a reference, and serve as a supplementary report to another paper dealing with the mine when further developed.

The plans and sections accompanying the paper will help to throw light on the geology of the ore-bodies, and the diagrams represent as nearly as possible the natural appearance of the ore-sections.

General.—The ore-bodies of the Silver Spur are located on Gunyan lease, 3½ miles north of the Dumaresq river, the border between New South Wales and Queensland, and about 7 miles east of Texas, and 54 miles south-west of Stanthorpe, in the Darling Downs district.

The area in which they occur is situated near the base and western slope of the main range, on the divide between the waters of Warroo and Pike creeks. The passage from the hills to the narrow valleys extending to the Dumaresq river is somewhat abrupt, consisting for the most part of steep sloping ridges and spurs, rising into dome-shaped hills. Owing to the conformation of the country the numerous creeks which drain the area and fall into the Dumaresq river are mostly dry during the summer.

The country is open forest-land, the timber consisting of ironbark, box, apple-tree and cypress pine with some currajong and brigalow.

Geology.—The predominating rocks of the area covered by the sketch-maps (Figs. 1 and 2, Plate VI.) are sedimentary, and belong to the Permo-Carboniferous period. They consist for the most part of grey and buff shales, sandstones and conglomerates, and lenticular masses of un-fossiliferous limestone, with quartzites on some of the ridges and hills. These beds have a variable strike, ranging a few degrees east and west of north, the general trend in the neighbourhood of the ore-bodies being north 10 degrees to 40 degrees east, and the dip is easterly at angles varying from 40 to 80 degrees.

The shales generally present an uniform appearance at the surface with the same lithological characters; in depth they change to a dark bluish-grey and appear to merge into beds of compact sandy claystones. They contain rounded, flattened pebbles of quartz and quartzite and occasionally large and small pebbles and fragments of granite. The granite-fragments appear to be confined to certain beds: they have been met with at a depth of 90 feet below the surface in the Silver Spur mine (No. 1 shaft). A large block, weighing about 15 cwts., was exposed in a trench near the surface, in Lease No. 66, of a coarsely crystalline variety containing muscovite. Similar fragments of granite have been noticed in the Gympie Beds by Mr. W. H. Rands, the assistant government geologist.

Sandstone-beds are rarely met with, and appear to pass by insensible gradations into shales; they occur as narrow bands of local extent, of a red or yellow colour, friable and fine grained in texture.

The conglomerates are claystones, with numerous circular and oval discs of siliceous shale, sandstone and quartz: granite has not been noticed in these beds.

The limestones occur as large and small isolated patches, mostly lenticular masses between the bedding-planes of the shales. They project as much as 20 feet above the surface and have been scored and grooved by weathering. They do not appear to contain organic remains, and have very irregular outlines.

The writer may mention that some of the shale-beds are saliferous, marsupials and the cattle on the run forming "licks" where they are exposed in the creeks. The alluvium in the flats along the base of the hills, formed from the detritus of the sedimentary rocks, where it is exposed by the creeks running through it, has been undermined by these "licks."

Igneous Rocks.—Diorite is the only intrusive rock that occurs hereabouts; it belongs to the quartz-diorite variety and contains abundance of hornblende. It is a moderately-coarse crystalline rock, and occurs in dykes having a general strike of north 30 degrees west, and varying in thickness up to 40 feet.

THE ORE-DEPOSITS.

Several small deposits of copper and argentiferous lead-ore have been worked intermittently for some years past in the district, but have not yielded remunerative results.

Silver Crown.—The only ore-deposit now being worked, other than the Silver Spur lease, is the Silver Crown, distant about 4 miles east of the Silver Spur and south of the old mail-track to Glenlyon. The shales here strike east-north-east and dip east-south-eastward. The ore occurs as small detached pockets of ferruginous copper gossan, outcropping to the east of a sandy shale, containing numerous quartz-veins, from which it is distant some 30 feet. The joints in the shales, dipping north-north-eastward at varying angles, contain small veins of ore; where these are intersected by other joints dipping north-north-west and west, the ore makes, forming pockets and lenses occasionally opening out to 30 inches wide by 4 to 5 feet in length, tapering out along the strike of the joint dipping north-north-east. At a depth of 50 feet below the surface, the ore presents the same characteristics, but contains both galena and copper-pyrites. It assays from 5 to 40 ounces of silver per ton and up to 11 per cent. of copper.

Silver King.—This mine is situated about 2 miles north-north-west of the Silver Spur. It is located in the same belt of country as the Silver Spur, and is 1,600 feet above sea-level. The shales in the neighbourhood contain lenses and pockets of limestone which present a brecciated appearance on the weathered surface, owing to the inclusion of fragments of shale. Veins and nests of quartz also occur in the limestone.

The ore-body corresponded in strike and dip with the bedding of the enclosing shales: the line of strike being north 10 degrees east, and of dip west 10 degrees north at a steep angle. The outcrop consisted of carbonates of lead and copper with some quartz and argentiferous iron-oxides, its length was over 30 feet and greatest width 5 feet. The lode consisted for the most part of shale which had been impregnated and partly replaced by metallic minerals, the replacement having taken place without materially altering the appearance of the rock. There were no defined walls, the ore-material gradually disappearing, until at a depth of 30 feet small pockets of carbonate of lime with some galena were met with; it thinned out at the northern and southern ends also. At the northern end, in sinking the shaft, numerous large and small pockets of spongy cellular material were passed through; they consisted of a skeleton or framework of clay, lime and oxide of iron, the cells being filled with earthy oxide of manganese and clay, and containing at their lowest part a little carbonate of lead and copper. This material gradually passed into the brecciated limestone. The shales curved round these bodies, and were smooth and crushed in contact with them, as if the pockets had expanded by increase of their metallic contents during their formation, or the "country" had contracted or squeezed around them: this was more noticeable at the base of the pockets.

Between 30 and 40 tons of ore from this mine yielded at the rate of 50 ounces of silver to the ton and 5 per cent. of lead.

Texas Copper-mine.—This mine is distant 2½ miles west of the Silver Spur; it was worked by a company for some 3 years previous to 1894. The country-rock, consisting of claystones of a greenish colour, is harder and more siliceous than the shales on the east. The cap was represented by a mass of siliceous ironstone containing a little carbonate of copper, below which was a bedded lenticular mass of blue and green carbonates of copper, which had a lateral extension of 40 feet by a width of 3 feet and appeared to cut out at a depth of 60 feet below the surface, the footwall being smooth and well-defined. Work was stopped here and a large shaft started on a fault to the north, the flucan of which contained a little copper gossan, derived from the decomposition of chalcopyrite. This shaft was carried down to a depth of 150 feet and ground stoped out on each side of the shaft along the fault, small but isolated patches being met with. The results were not satisfactory. No prospecting was done on the site of the first discovery of ore.

At several localities in the neighbourhood bedded veins of quartz crop out; they are somewhat vesicular, from the decomposition of pyrites, and generally yield a trace of gold; veins of quartz containing copper-glance have been met with. Native copper has been found in the amygdules of a basic, much altered volcanic rock, resembling dolerite, 3½ miles east of Schneider's selection. Ores of antimony and arsenic, hæmatite, and limonite occur in the surrounding region. These deposits, with the exception of the antimony, have not been worked; they appear to be small lenticular bodies associated with quartz.

THE SILVER SPUR MINE.

General Characteristics.—The ore-bodies are developed in proximity to a diorite-dyke, and consist of lenticular masses approximately parallel to each other and intercalated with the shales (Figs. 1 and 2, Plate VI.). They are apparently confined to beds of soft dark bluish-grey shales which have been subjected to considerable local movement along the bedding-planes; these movements, however, do not appear to extend for any great distance along the strike of the rock. The shale-beds are confined between hard compact siliceous claystones.

The length of the ore-bodies up to the present has not exceeded 150 feet by a width of 40 feet. The strike varies from north 7 degrees east to north 55 degrees east and the easterly dip from vertical to 72 degrees. They occur near and in contact with a fault striking north 50 degrees west. They have been opened up to a depth of 150 feet, and found to vary from 2 to 40 feet in width, by 150 feet in length. The zone of oxidation does not extend beyond a depth of 90 feet, water being met with at 92 feet from the surface in No. 1 shaft. The ridge on which the ore-bodies crop out is 1,400 feet above sea-level.

No. 1 *Lode.*—The No. 1 ore-body (Fig. 2, Plate VI.), distant about 600 feet south-west from the diorite-dyke, strikes about north 10 degrees east and underlies to the east about 72 degrees. It was marked by a strong outcrop of copper-stained ferruginous quartz and iron-ore, rising 2½ feet above the surface, by 10 or 12 feet in length, the surface for some distance to the south being strewn with fragments of ore (floaters) embedded in a stiff clay which assayed from 3 to 14 ounces of silver per ton. This ore-body has been proved and opened up to a vertical depth of 142 feet by about 80 feet in length (Figs. 3 and 4, Plate VI.).

The oxidized portion, which extends to a depth of 95 feet on the foot-wall side, consists of a mass of vari-coloured oxide of iron intermixed with ferruginous and vesicular quartz, the whole being stained more or less with carbonates of copper (blue predominating); carbonate of lead occurred among the softer varieties of ore and in large and small pockets of a friable, granular, and semicrystalline character. A large patch of "tile-ore" was worked on the hanging-wall side between the 30 feet and the 90 feet levels; it was rich in copper, but averaged only 8 ounces of silver per ton. White vesicular quartz containing small crystals of cerusite, assaying up to 80 ounces of silver per ton, was met with at the northern end of the ore-body, between the 30 feet and 60 feet levels. Small vughs, filled with clay resembling lithomarge and having a finely laminated appearance, occurred in various parts and towards the centre of the ore: this clay averaged 11 ounces of silver per ton.

Native silver occurred sparingly in superficial coatings on the wall-rock and quartz near the tile-ore. In the same locality, a few small specimens of chalcotrichite in capillary crystals, associated with cuprite, were found.

The gossan-ore was devoid of show-specimens and contained no "mullock;" its average value per ton was:—Silver, 30 ounces; gold, 20 grains; copper, 2½ per cent.; and lead, 5 to 6 per cent.

The ore-body as a whole presented a banded appearance, running parallel with the bedding-planes of the wall-rock; it was divided into parallel floors from 2 to 5 feet apart, horizontal near the fault, and they dipped southward 30 to 40 degrees near the shaft. These floors in several instances were found to correspond with joints in the wall-rock, being continuous with them. In the softer portions of the ore-body, they were filled with clay, but in the harder portions the floors were often 1½ inches apart and generally filled with carbonates of lead and copper.

The walls, although somewhat irregular, were fairly well-defined, the ore but rarely adhering to the rock, and showed no general movement; the joints in places showed slickensides: as did also the bedding-planes at the southern end of the lode. Most of the movements and slickensides appeared to have been caused by pressure from the ore-body itself, as these crushings were local and occurred generally where the ore curved outwards.

At the 60 feet level north (Fig. 3, Plate VI.) the ore passes to the right and left of a mass of crushed shale. At this point, for a space of 3 feet, there is no marked difference between the rock and ore, the former gradually passing into the latter, the colour of the rock changing from grey to dark blue-brown or brick-red and so merging into the gossan. The joints and bedding-planes in the rock are lined with steatite, the rock containing numerous grains and small pockets of blende and pyrites at this point. The rock is greatly crushed, and appears as if it were squeezed and bent round by the growth of the ore-body.

A little soft and friable sulphate-ore occurs where the zone of oxidation commences; beautiful crystals of native sulphur were found lining the joints in the ore, also sulphate of lime. Below these products of decomposition, the sulphides occur massive; they consist of a dense, compact, finely crystalline body of galena and blende, containing patches and parallel bands of an intimate mixture of copper- and iron-pyrites; a few isolated patches of a coarser-grained variety of galena and blende occur occasionally. The floors and joints are lined with pure white silicate of alumina, which is soft and gives an acid reaction.

The ore-body appears to be underlying rapidly towards No. 2 shaft and has made along the fault at the bottom-level (142 feet) thus connecting the two ore-bodies. The average value of the ore (sulphide) per ton is :—Silver, 16 ounces ; gold, 1 dwt. ; copper, 2 per cent. ; and lead, 5 per cent.

Between the 90 feet and 142 feet levels, the hanging-wall rock is greatly crushed and collapses when the ore is removed, or frits away until the siliceous claystone is reached. At the lower level, on the foot-wall side, a band of rich auriferous mispickel occurs ; and this is the first time that this mineral has been seen in the mine. The following is an analysis of the sulphide-ore from No. 1 shaft :—

	Per Cent.
Silica	26·35
Sulphur	27·83
Iron	24·57
Zinc	11·40
Lead	6·46
Copper	2·20
Oxide of manganese	1·19

No. 2 *Ore-body.*—The gossan-ore extended to a depth of 60 feet below the surface, and did not differ materially from that of No. 1 lode. It was smaller than the latter, contained more lead carbonate, and was more irregular in shape, the foot-wall being well defined between the 60 feet level and the surface, and the ore underlying slightly to the west.

At 40 feet south from the shaft, at the 56 feet level, the ore appeared to cut out, but later developments proved the existence of a parallel vein of ore, overlapping No. 2 lode, projecting past it inside the foot-wall, and separated from it by about 4 inches of shale. It was from 8 to 12 inches wide by 20 feet long, and when stoped towards the surface opened out into a large body of good ore resembling No. 3 lode in character. As the surface was approached, the overlap gradually disappeared until the two ore-bodies almost touched each other.

At the 142 feet level, the sulphide-ore which had been rapidly thinning out has again increased in size against the fault, and appears to be widening as the shaft goes down. At the present depth of the shaft (190 feet), the ore assays 100 ounces of silver per ton, and contains more iron-pyrites than usual (Fig. 5, Plate VI.).

No. 3 *Ore-body.*—This lode is situated 200 feet south of No. 2 shaft. The outcrop consisted of a few large ironstone-boulders, differing in appearance from No. 1 lode and showing no copper stains. These were embedded in stiff clay, which contained fragments of ore scattered through it, and assayed from 6 to 18 ounces of silver per ton.

In general character this lode was similar to No. 1, but the walls were better defined, showing a greater amount of movement between the 50 feet and 142 feet levels. As the ore was stoped towards the surface the hanging-wall was very irregular, and in several places the ore extended beyond the shale-beds into the more siliceous claystone, forming irregular pockets of sandy, friable lead carbonate with minute quantities of ruby silver, which crumbled away when touched.

During stoping operations at the 50 feet level, a record of the daily assays was kept showing the distribution of the silver in the lode (Fig. 6, Plate VII.). The limit of oxidation was 75 feet below the surface (Fig. 7, Plate VII.), which corresponds, taking into account the difference in level, with 90 feet in the No. 1 lode.

The sulphide-ore has been explored to the same depth as the No. 1 lode, which it much resembles in appearance, but it contains less zinc, more copper- and iron-pyrites, and assays higher in silver. At the 142 feet level, the ore has been opened up for a distance of 150 feet, averaging 5 feet wide, the ore reaching up to the fault, which has a greater extension eastward than in the upper part of the lode. This ore-body is divided by horizontal floors having a slight southerly dip; they are generally lined with silicate of zinc and in several instances form cavities, the floor of which was strewn with fragments of the ore cemented together by the silicate of zinc.

For some weeks, a steady flow of carbonic acid gas proceeded from these joints near the centre and eastern corner of the drive; and, as the work progressed, this discharge was traced to a fissure in the country-rock on the eastern side of the level. It has been flowing for about 4 months, and still continues.

The vein-walls—shales—at this level are somewhat chloritic, and appear to have been subjected to great lateral pressure. This crushed and broken country, according as the width of the ore varies, extends back a foot or more to the siliceous claystone, which presents a hard smooth surface, being a case of "walls within walls." As the ore is stoped, the shale falls away from this second wall in large and small, elongated, lozenge-shaped masses. Here, as elsewhere, are small bedded veins of milky quartz, seldom containing metalliferous minerals, which frequently show small horizontal planes of faulting. Another interesting feature in connexion with these beds is the occurrence of oviform pebbles, and boulders of quartz which show faulting.

No. 4 Ore-body.—This ore-body was met with in prospecting to the north-west along the fault at the 60 feet level from No. 1 shaft, at a distance of about 66 feet from the end of the level. It was very irregular in shape, possessing no defined walls, the wall-rock being saturated with metalliferous minerals in proximity to the ore, and containing pockets of carbonate of lead (Fig. 8, Plate VII.). Its length was 30 feet and its average width 3½ feet; it extended to within 37 feet of the surface, and pinched to about 6 inches in width at 20 feet below the 60 feet level, where sulphide-ores made their appearance. The gossan was extremely dry and friable, and resembled that of No. 3 lode in character, but contained more lead and less copper, zinc and silica.

A small patch of lead carbonate was mined at the surface between the Nos. 1 and 4 shafts; it extended to a depth of 30 feet below the surface at the fault, gradually pinching out, and having little lateral extent.

SUMMARY.

The ore-bodies at the Silver Spur mine are splendid examples of lodes formed by replacement of country-rock.

Here is a line of fault crossing shales of varying composition, by which mineral-bearing solutions have reached the shattered beds. The minerals have dissolved out, and taken the place of, the aluminous shales, and in so doing have assumed their very habit and appearance. The floors, joints and cracks of the shales reappear in the ore, and thus in many cases can be seen running continuously from the shale into the ore.

It would even appear that the formation of ore is still going on, both above and below the oxidized zone, as evidenced in No. 1 lode at the eastern end of the 60 feet level, and in No. 3 lode at the 142 feet level.

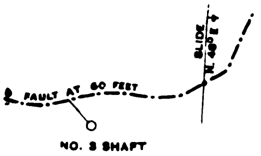
The plans and sections attached will speak for themselves, and render plainer what has been said above.

PLATES VI. AND VII.

Figs. 1 and 2.—Showing outcrops of ore-bodies, and also below the surface at about the various levels. The plan (Fig. 2) includes the latest developments at the 200 feet level.

Fig. 3.—No. 1 ore-body at the 60 feet level, showing the bedding-planes of the shales following the outlines of the ore in places. The shales on the north, between the gossan and the fault, blend with the gossan at the extremities of the beds, the change being so gradual as to be hardly distinguishable. The shales are jointed with veins of steatite.

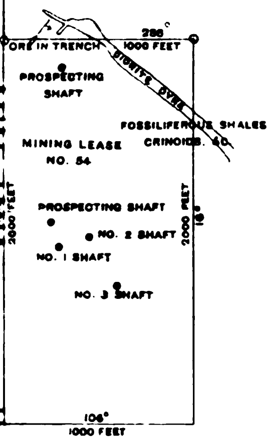
land."


SLIDE
N. 45° E.
FAULT AT 60 FEET
NO. 3 SHAFT

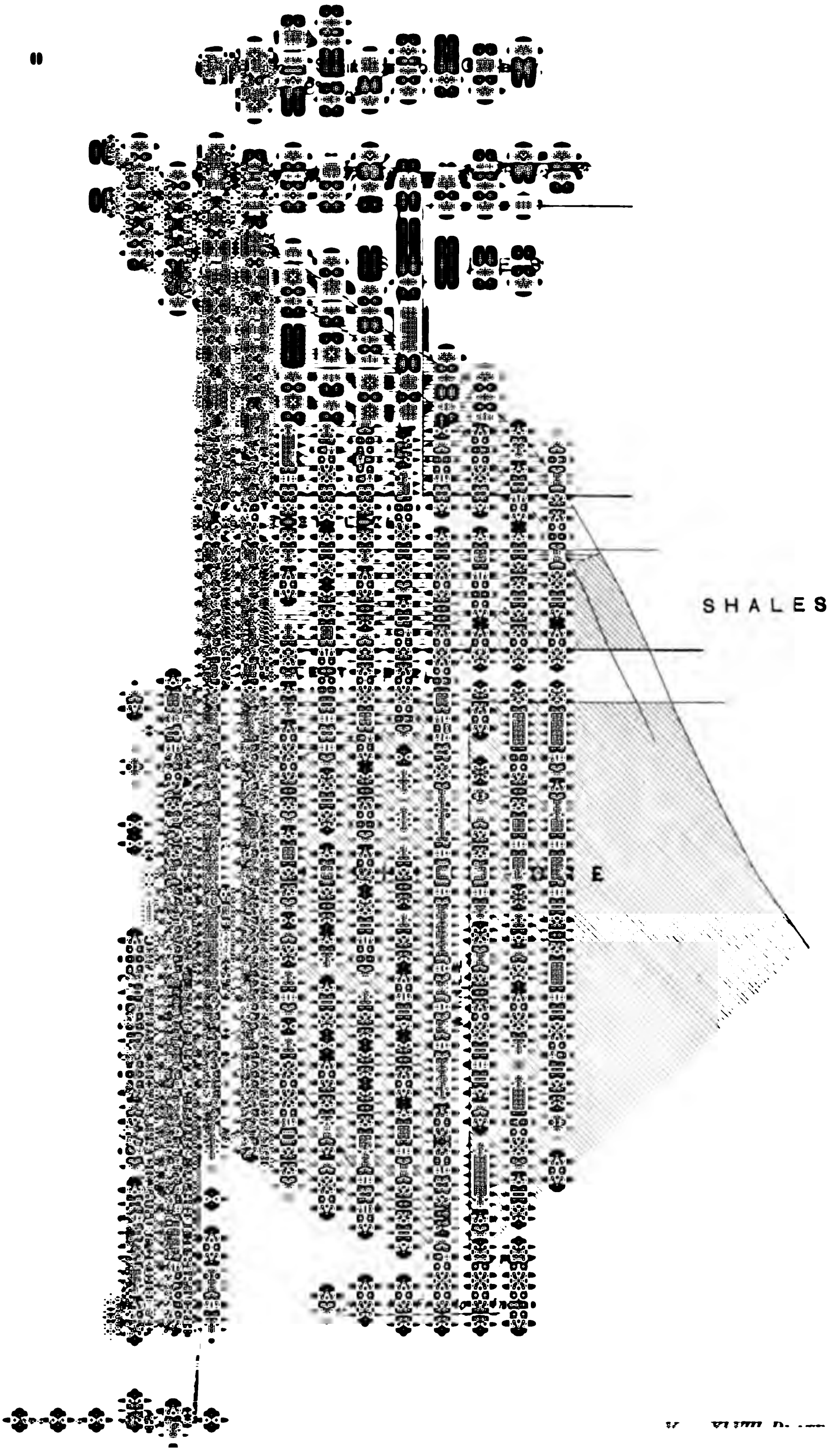
alc. 60 Feet to 1 Inch.

Fig. 1.

Plan of Mining Lease—No. 54, and Adjoining Leases.


286°
1000 FEET
ORE IN TRENCH
DIORITE DYKE
PROSPECTING SHAFT
FOSSILIFEROUS SHALES
CRINOIDS, &c.
MINING LEASE
NO. 54
2000 FEET
2000 FEET
PROSPECTING SHAFT
NO. 2 SHAFT
NO. 1 SHAFT
NO. 3 SHAFT
106°
1000 FEET

Scale, 1000 Feet to 1 Inch.


SHALES
E

References.—*a*, Silicious quartz ore, averaging 30 to 40 ounces of silver per ton. *b*, White quartz, seamed and lined with oxide of iron, poor. *c*, Pockets of lithomarge, assaying 11 ounces of silver per ton. *d*, Showing alteration of shales into gossan, near contact with ore; there is no clear line of demarcation, the replacement being very gradual. *e*, Unaltered shales.

Fig. 4.—Section of No. 1 shaft along line A-B, Fig. 3 (60 feet level, No. 1 ore-body). The quartz from the 60 feet to the 90 feet level was poor in metallic minerals; the sulphide-ore contained over 20 per cent. of zinc near the centre of the ore-body.

Fig. 5.—Longitudinal section between No. 2 and No. 3 shafts up to the fault. The sulphide-ore is in contact with the fault at the 142 feet level.

References.—A, Fault, north of No. 3 shaft. B, Fault, north of No. 2 shaft.

Fig. 6.—Plan of the 50 feet level, No. 3 shaft, showing assay values of the gossan-ore in silver.

References.—*a*, Average ore in this zone, 45 ounces of silver per ton. *b*, Average, 60 ounces of silver per ton. *c*, Average, 90 ounces per ton. X, is placed where native-silver occurred.

Fig. 7.—Longitudinal section along the strike of No. 3 ore-body, between the surface and the 70 feet level. The horizontal shading shows the ore pinching somewhat like the keel of a ship; these portions of the ore were high in silver.

Fig. 8.—Plan of the 40 feet level, No. 4 ore-body, the appearance being as near the original as possible. There is no faulting apparent along the joints to the west in contact with the ore. The wall-rock appears everywhere to have been eaten into and replaced by the mineral solutions.

In drawing these plans, accurate measurements were taken every 2 feet (and less) and no trouble was spared to make them as complete as possible.

APPENDIX.

Since January, 1898, No. 2 shaft has been sunk to the 200 feet level, and drives have been opened out in an easterly and westerly direction along the fault, proving the existence of large payable bodies of ore. This ore is similar in character to the sulphides at the 150 feet level, containing, however, more carbonate of lime, iron-pyrites, and arsenical pyrites, with small irregular masses of proustite and pyrargyrite. Several of the smaller ore-bodies at this level occur along cross-joints, instead of following the bedding-planes of the shales. As heretofore, they appear to be confined exclusively to the blue shales.

The fault at the 200 feet level, although irregular in dip, may be considered as vertical; the throw has not yet been determined, but the writer believes that the displacement is slight, and that the ore-bodies have been formed subsequent to the faulting.

The meeting was then closed.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD AT FURNESS ABBEY, JULY 12TH, 1899.

MR. J. L. HEDLEY, VICE-PRESIDENT, IN THE CHAIR.

The TOWN CLERK OF BARROW (Mr. C. F. Preston) wrote that he was requested by the Mayor (Mr. Alderman Chapman) to say that an official engagement prevented him from attending the meeting of members that morning.

The SECRETARY read the minutes of the last General Meeting.

Mr. W. LECK read the following paper on "Fire-damp in the Iron-ore Mines of Cumberland and Furness":—

FIRE-DAMP IN THE IRON-ORE MINES OF CUMBERLAND AND FURNESS.

BY J. L. HEDLEY AND WM. LECK, H.M. INSPECTORS OF MINES.

The visit of The North of England Institute of Mining and Mechanical Engineers to the Furness district was suggested to the writers as a desirable and opportune occasion on which to present a short paper dealing with above subject from an essentially practical standpoint.

To many people, however, and probably to none more so than to the bulk of the persons employed in connexion with the iron-ore mines of Cumberland, the title of this paper will appear as somewhat of a misnomer, inasmuch as the majority of Cumberland iron-ore miners have, happily, never come into contact with the dangerous gas known as fire-damp.

Until last year, indeed, the Cumberland iron-ore mines, with one exception, were entitled to claim entire immunity from the visitation of this insidious and unwelcome agent.

The exception referred to is the Montreal mine, situate at Cleator Moor, and, although gas has from time to time been noted there, it should be mentioned that no accidents have been recorded, probably owing to the fact that the officials, having a practical knowledge of the nature and properties of fire-damp, take the precaution to carefully inspect with locked safety-lamps any place where it is likely to generate or accumulate. Montreal enjoys the unique distinction of being both a coal and iron-ore mine, both minerals being drawn up the same shaft.

The only other iron-ore mine in Cumberland where fire-damp has been reported is at Hodbarrow, by far the largest and most important metalliferous mine in the district. It was not until August, 1898, that for the first time the presence of gas was there discovered, and then a small quantity, which had collected in a cavity in the roof, ignited at a miner's candle. The injuries inflicted were very slight, and the man went on with his work.

Most of the Furness iron-ore mines have had some experience of fire-damp, but not in large quantities. Although the accumulations of fire-damp in these iron-ore mines have never reached such an extent as to create the dreadful havoc and destruction too often experienced in coal-mines, yet the records show that fire-damp is a factor which must be reckoned with in winning iron-ore in this part of the district.

During the last 7 years 10 accidents from explosions of fire-damp in iron-ore mines have been reported, whereby 12 persons were more or less seriously injured. The only fatal accident from this cause which has occurred in the district took place at the Mouzell mine, near Dalton, in 1888, when a man was so severely burned that he succumbed to the injuries received.

There can, the writers think, be no question as to the source or origin of fire-damp in any of the mines hitherto investigated.

At Montreal mine, Cumberland, the iron-ore is found in close proximity to coal, the coal-fault forming the boundary of the iron-ore. In this mine, the geological formation is an all-sufficient explanation of the presence of gas, and it is not surprising that under these conditions gas is met with in working the iron-ore.

The methods adopted in mining the softer ores of Furness are largely the same as those in use at the Hodbarrow mine, in Cumberland, and the presence of gas, at both of these places, may be directly traced to the same cause, namely, the decomposition of mining-timber, especially in places where water is percolating.

The accidents investigated have all occurred in places where old and decaying timber was present in large quantities, and in no case has gas been discovered in the Furness iron-ore mines in opening out new or virgin ground.

The reason why gas has not been found at the Hodbarrow mine, until recently, is probably owing to the fact that this mine is younger than those in Furness, where explosions have occurred, and the process of decomposition of timber is not therefore so far advanced.

Fire-damp being lighter than air, would naturally be expected near the roof, and especially in rise-workings, hence the writers find that most, though not all, of the accidents occurred through small quantities of gas collecting amongst the old timber which forms the roof of ordinary working-places.

These mines are all worked with open lights, and the actual explosion has usually been caused by the miner pushing his candle into the interstices or cavities among the roof-timber—of course in complete ignorance of the fact that gas was lodging therein.

Old workings, which had been abandoned for some considerable time and were only partially closed, were, on being reopened, responsible for some of the accidents, and although, as previously observed, the gas is not met with in large quantities, there was sufficient to inflict on the persons concerned more or less serious burns.

In view of the peculiar nature of the accidents, and owing to the fact that they may occur at any moment, inasmuch as the miners, generally speaking, have had little experience of fire-damp, it behoves the officials responsible for the management of each mine to take precautions similar to those adopted in coal-mines, and to have each working-place examined with a safety-lamp prior to the commencement of ordinary work—proceeding on the prudent assumption that as gas is generated in the mine, its occurrence may be expected in any part thereof. The practice of examining part of the mine with safety-lamps and part with open lights is unwise, and has been the cause of many accidents in coal-mines in the past.

Good ventilation is, of course, essential in every mine, both for the health of the workmen, and in order that pernicious gases may be safely diffused, nevertheless the above-mentioned precaution should never be relaxed.

In conclusion, the writers may be permitted to express the hope that —inasmuch as the Metalliferous Mines Regulation Act, 1872, has never been amended, so far as its safety-provisions are concerned—an amending Act may become law at an early date. The provisions of the existing Act are unsatisfactory and incomplete, and although the writers have pleasure in stating that mine-owners, as a rule, have gone far beyond its requirements, so far as the safety of the workers is concerned, it is at the same time exceedingly desirable, in the interests of all concerned, that an Act of a moderate nature should be passed with the view of bringing the regulations affecting metalliferous mines into line with modern requirements.

Mr. **Henry Ayton** (Newcastle-upon-Tyne), with regard to the last paragraph in the paper, thought that there was already too much legislation relating to mines. H.M. inspectors of mines admitted that owners and managers of mines exercised greater precautions than they were required to do by Act of Parliament, and he did not see why they should ask the Government to make them do compulsorily what they were at present doing voluntarily.

Mr. **Cedric Vaughan** (Millom) said that the accident described in the paper was the first which had occurred from the accumulation of gas in the Hodbarrow mine, but since the paper was written, a second accumulation had been found, in a drift in close proximity to old workings. Its presence was ascertained in time by means of a safety-lamp, and steps were immediately taken to clear the place of gas. The occurrence showed that where there was a quantity of old timber in process of decomposition, the presence of gas was to be suspected, and steps should be taken to guard against its accumulation. The Hodbarrow mine had been working for about 40 years, and gas had only been discovered on the two occasions mentioned.

Mr. **W. I. Barratt** (Millom) supposed that the suggestion as to the examination of the working-places only referred to portions of the mine where the presence of gas was known.

The **Chairman** (Mr. J. L. Hedley) said that the suggested examination would apply to all working-places.

Mr. **J. Cartmell Ridley** (Newcastle-upon-Tyne) said that it would be of interest to have an exact description of the gas and of the reactions occurring from the decaying timber.

Mr. **Bennett H. Brough** considered that the authors' paper was one of very great value in that it directed attention in a practical manner to the fact that gas was met with in metalliferous mines more frequently than was usually thought to be the case. In a paper* contributed to the Institute 10 years ago, he had given a history of the occurrence of gas in metalliferous mines, and brought forward evidence to show that all the occurrences observed were not due to the same cause, but might be explained by eight different hypotheses, the one most generally applicable being that the decomposition of timber in a mine, in a manner similar to the decomposition of vegetable matter in marshes, might produce fire-damp which would accumulate in cavities. Messrs. Hedley and Leck's observations tended to support that hypothesis. It was also supported by the recent observations of Mr. J. Libert,* who recorded five cases in which fire-damp had been encountered in iron-ore mines in the province of Namur, and also by those of Mr. Lodin,† who described gas-explosions in the mines of pisolitic iron-ore in Alsace. That hypothesis was, however, not applicable in all cases. For example, Prof. G. Nordenström‡ had recently found that inflammable gas issuing from borings in the Dannemora iron-mines contained 33·6 per cent. of marsh gas and 66·4 per cent. of nitrogen. In that case, the gas had certainly not been derived from the decomposition of timber under water. It was curious to note that gas-occurrences similar to those described by the writers had been observed in metalliferous mines more than 200 years ago. Thus, the celebrated Jesuit, Athanasius Kircher, devoted a chapter of his great Latin work *Mundus Subterraneus* (1678) to mine-gases, and described the occurrence of inflammable gas in the Herrengrund copper-mine, near Neusohl, in Hungary. Gottfried Moller in his treatise *De aere fodinarum metallicarum noxio* (1730) described an explosion of gas at an abandoned shaft in the Carl adit at Sandberg. According to Stelzner's *Beobachtungen über Grubenwetter* (1786), 12 miners lost their lives by a fire-damp explosion in a silver-mine at St. Andreasberg in 1694. The occurrence of fire-damp at the Idria mercury-mines and at the Weitwiesen iron-mine in Salzburg, was also recorded. In all these ancient examples, the origin of the gas appeared to have been similar to that of the fire-damp in the iron-ore mines of Cumberland and Furness. Reference to them might, therefore, perhaps not be out of place in the *Transactions*.

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* *Transactions of The North of England Institute of Mining and Mechanical Engineers*, 1889, vol. xxxviii., page 59.

Mr. GEORGE SCOULAR (Whitehaven) asked if gas had been found only in wet or damp mines. Many of the iron-mines in the Whitehaven and Furness districts were quite dry, and it would be well to know if it was safe to reckon upon immunity from gas in such mines.

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* *Annales des Mines de Belgique*, 1899, vol. iv., page 48.

† *Annales des Mines*, 1895, vol. viii., page 40.

‡ *Geologiska Föreningens i Stockholm Förhandlingar*, 1896, vol. xviii., page 637.

Mr. **Miles Kennedy** (Ulverston) remarked that he had always found the gas in the driest parts of the iron-ore mines.

Mr. **W. E. Walker** (Whitehaven) remarked that in Cumberland his experience had been that gas was only produced where the timber was dry and he had never found it where the timber was wet.

Mr. **W. Leck**, replying to the discussion, said that there had been practically no legislation with reference to metalliferous mines since the passing of the existing act in 1872. More than a quarter of a century had elapsed since that time, and with the advent of a new generation, different conditions had arisen, which necessitated further legislation. It was certainly true that most mine-owners were in advance of legal requirements, but a new act would bring up some of those owners who were somewhat laggard, and it was only fair that all should be put under the same conditions.

He was unable to give the composition of this gas, as it had hitherto been impossible to obtain a sample for analysis. The gas had always been found in small quantities, and was therefore easily diffused. In every accident which he had investigated the gas had been dispersed before his arrival.

Actual experience of these accidents showed that the gas accumulated for the most part in places where water was exuding from the roof. In one case, which occurred recently, the working-place was absolutely dry when the men went away at night, but when they returned the next morning they found that during their absence a piece of stone had fallen from the roof, leaving a small hole through which water was percolating. A miner pushed his candle into the hole, and an explosion occurred, by which he was burned. The water evidently assisted in the decomposition of the timber which produced this gas, and so far as they could ascertain, the latter was of the same nature as ordinary fire-damp.

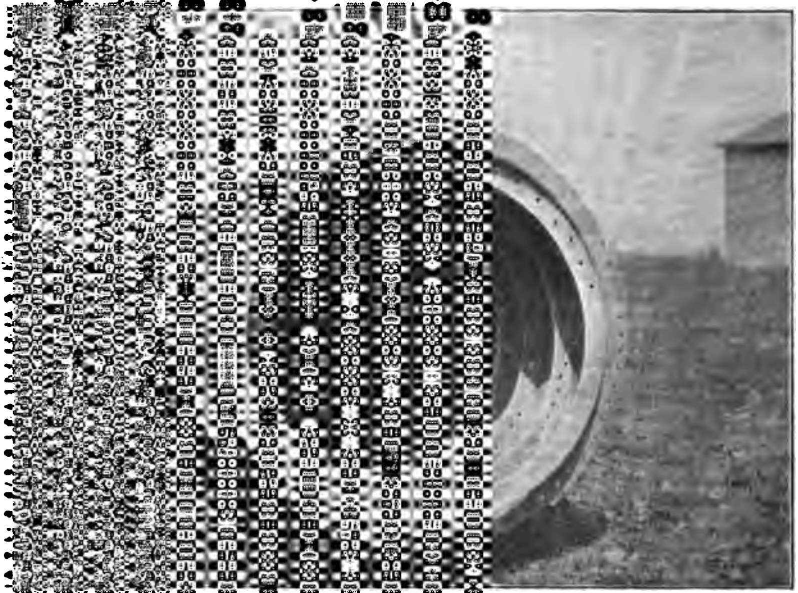
Mr. **G. Scoular** proposed a vote of thanks to the writers of the paper, and it was cordially approved.

Mr. **William Kellett's** "Description of the Machinery and Process of Iron-ore Washing at the Park Mines, in the Furness District of North Lancashire," was taken as read.

[illegible] Y AND PROCESS OF [illegible] PARK MINES, IN THE [illegible] LANCASHIRE.

[illegible] INEER, WIGAN.

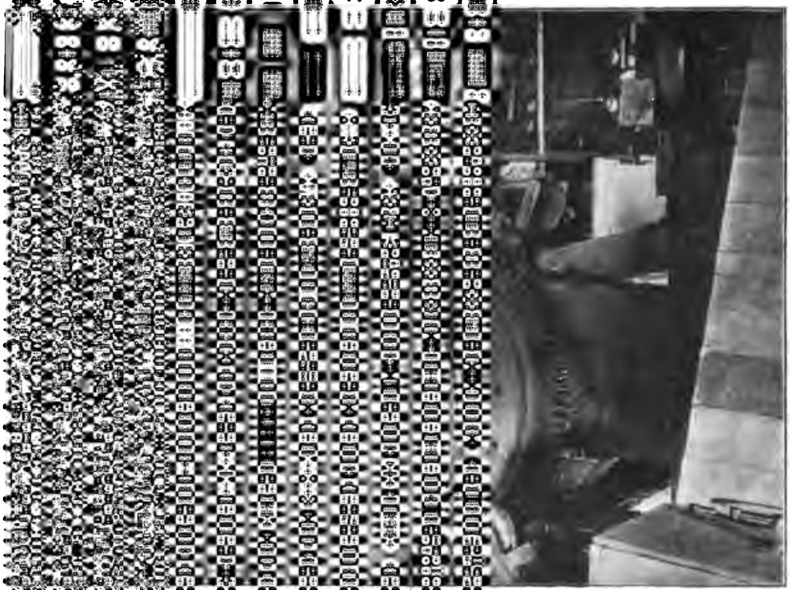
[illegible] nced is, except as to a small [illegible] f the mines to permit of its [illegible] ing-furnaces, with no other



[illegible] Double-threaded Worm

[illegible] of clay or stone that may be [illegible] mine-waggons into the rail- [illegible] he district, however, a small [illegible] and and clay as to make it [illegible] ing before sending it to the [illegible] posit are of this description. [illegible] process adopted for washing of the ore, from the good; the impure ore is sent out t to a common depot near of hoppers into which the waggons or bogeys which most floor of the washing-

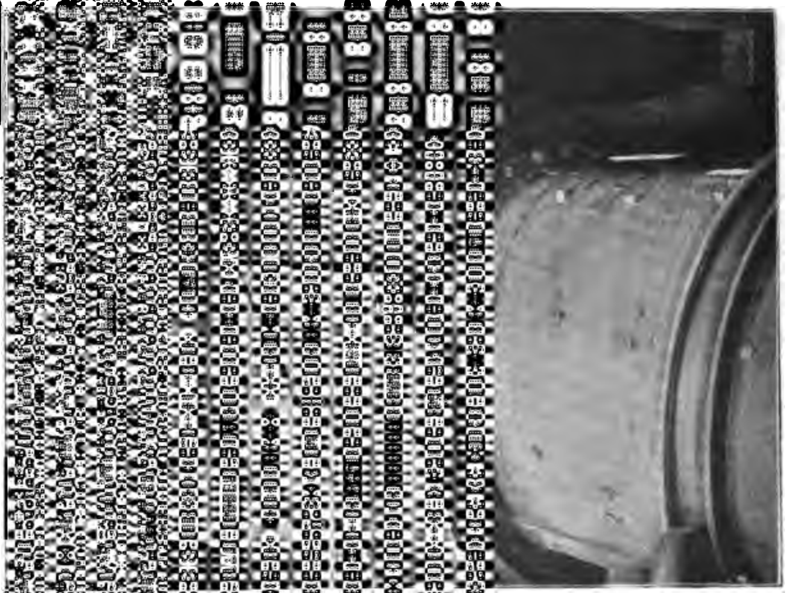
ting and washing the ore Blake stone-breaker, and a ween the jaws to assist it



Revolving-drum.

s to crush the clayey lumps

tream of water, drops into a d with cast-steel blades or lumps and secure a regular ore next passes by means of essential part of the washing , 19 feet long and 4½ feet in ble-threaded screw or worm he drum at a pitch of 20 [illegible] the screw are furnished [illegible] intake-end of the drum is [illegible] inches in diameter, and the [illegible] is perforated with ⅝ inch [illegible] ers travelling in steel rings [illegible] made to revolve by cog- [illegible] er minute. The drum is [illegible] d being elevated 19 inches [illegible] water is supplied near the



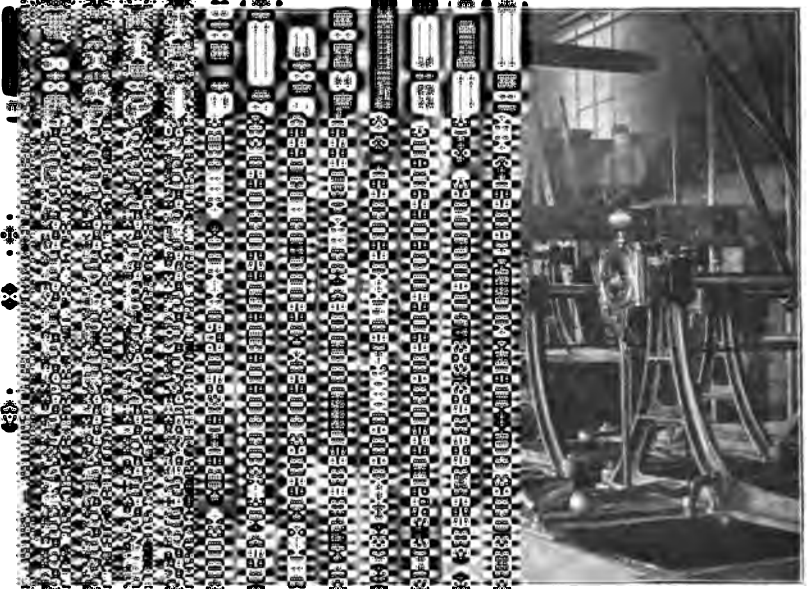
[illegible] Revolving-drum.

[illegible] eding-chute at the intake- [illegible] isintegrate, and travel the [illegible] water, which, passing out [illegible] with it the finer portions [illegible] reduced to a slime.

[illegible] harge-end of the drum, it [illegible] ubjected to a riddling pro- [illegible] off to the jiggers, and the [illegible] ating picking-table, where [illegible] cked out, and the cleaned [illegible] waggons. The unreduced

, which is placed under- of this disintegrator is m to go again through

onsisting of good ore and ntage of iron, but far too d the object of jigging other impurities. For seven different sizes, and



ter-trough fitted with ound.

e separation into the first mmels or perforated drums, $\frac{1}{4}$, $\frac{3}{16}$, and $\frac{1}{8}$ inch holes by means of pointed boxes the bottom of a trough

r pulsating type and have ves are made of perforated jigger corresponding with be dealt with. The good

tanks, and is then raised
the railway-waggons.
d the jiggers is conveyed
olving shaft furnished with
iron blades which traverse
down which flows a stream

d by a semi-portable Roby
and 16 inches stroke. The
nto connexion by means of

-jiggers.

. The quantity of material
hours is about 110 tons.
erent parts of the machinery

rated in a discharge-trough,
the water through water-
on to a waste-heap, and the
along a line of troughs.
istrate the principal parts of

The average working cost (excluding renewals to machinery) is 10·81d. per ton of clean ore delivered.

The average percentage of clean ore is 64·42 per cent. of the "washer-ore" put in, showing that there is 35·58 per cent. of waste stone removed in the washing process.

The CHAIRMAN (Mr. J. L. Hedley) proposed a vote of thanks to Mr. Kellett for his description of the ore-washing plant, which the members were to inspect.

The vote of thanks was cordially adopted.

Mr. JAS. DAVISON read the following "Description of the Pumping-plant at the Stank and Yarlside Mines in the Furness District of North Lancashire":—

DESCRIPTION OF THE PUMPING-PLANT AT THE STANK AND YARLSIDE MINES IN THE FURNESS DISTRICT OF NORTH LANCASHIRE.

By JAS. DAVISON.

The iron-ore mines of Furness are situated within the area of the Carboniferous Limestone of the district. This limestone is thickly-bedded and traversed by numerous vertical joints, in which there is frequently more or less open space. It is also subject to weathering, and lends itself to the formation of subterranean channels and caverns by percolating waters. These channels in many instances extend long distances and penetrate to great depths, forming underground watercourses which drain the surface of the country and convey large quantities of water into the mines that come in contact with them. There is also in the western part of the district a considerable fault running in a northerly and southerly direction, by which the limestone is thrown down westward to unascertained depths, and the Permian sandstone overlying it is brought into juxtaposition with the limestone on the eastern side of the fault. This sandstone is also proved to be a very heavy water-bearing rock.

The Stank and Yarlside mines are situated in the south-western corner of the Carboniferous Limestone area, close to the great fault, and extend eastward along the course of several veins. The workings of the mines have from time to time come into contact with several large caverns and underground watercourses, as described above, and considerable quantities of sand and water have been liberated on several occasions in the course of the development of the mines. Strong dams of concrete and brickwork, with heavy doors of pitchpine plated with steel to close on such emergencies, have been built. In one instance the volume of water that came away after blasting in one of the bottom-levels was so great that the men had barely time to climb the ladders to the upper working. The door, put in to protect the pumps, being open for the purpose of approach to the workings where the men were engaged, and there being no time to close it, the water rose so rapidly that in 15 minutes there was over 90 feet of water in the shaft. The pumps were worked for a month under water, without lowering it, and finally a diver was employed to go down and close the door.

The large quantity of water that has now to be dealt with being unforeseen in the earlier development of the mine, engines and pumping-plant of comparatively small size only were provided; but, as necessity has arisen, one pumping-engine and plant after another has been erected until, at the present time, there are 6 and sometimes 7 engines delivering water to the surface. About two-thirds of the water is pumped from the 720 feet level and one-third from the 420 feet level. The quantity of water pumped varies from a maximum of 6,860 gallons per minute in winter to a minimum of 4,940 gallons in summer. The average quantity per minute pumped during 1898 was 5,662 gallons, which is equal to over 8,000,000 gallons in 24 hours; and the maximum quantity in winter is 9,878,400 gallons in 24 hours.

Adit-levels are brought to the pumping-pits from the lowest points of the adjoining valleys, to shorten as much as possible the vertical distance of pumping.

The following table describes the types of engines and pumps with which the mines are now furnished and their dimensions:—

No. of Pit where Pumping-engine is Situated.	Type of Engine.	Diameter of Cylinder.	Length of Stroke.	Pumps.		Total Height of Column.	Remarks.
				Number.	Diameter.		
		Inches.	Feet.		Inches.	Feet.	
1	Cornish ...	40	9	1 ram	12	720	In 3 lifts
2	do. ...	72	8½	1 „ 1 „	15 12	720 720	„ 3 „ „ 2 „
5	do. ...	70	10	2 rams 2 „	15 12	338 426	„ 2 „ „ 2 „
7	do. ...	80	10	2 „	15	480	„ 2 „
10	Hathorn-Davey horizontal compound	33 : H.P. 60 : L.P.	10 : Double stroke	2 „	20	382	„ 1 „
11	do.	38 : H.P. 66 : L.P.	10 : Double stroke	2 „	20	550	„ 2 „
3	do. Geared 7 to 1	12 : H.P. 18 : L.P.	5 : Double stroke	2 buckets	18	232	Each bucket lifts to the adit-level

No. 11 *Pit.*—In addition to the above pumping-plants, there is also an auxiliary horizontal engine (with a cylinder 25 inches in diameter) formerly used as a winding-engine. This has been compounded and geared 5 to 1 to work two 24 inches rams, each 5½ feet stroke, pumping from the 720 feet level to the 558 feet level to supply the two 20 inches rams at the No. 10 Pit.

The No. 5 Cornish and the No. 11 Hathorn-Davey are the two pumping-engines (each one of its type) which do the largest amount of work. No. 5 pumping-engine averages throughout the year 5 strokes per minute, and delivers 238 gallons each stroke, equal to 1,190 gallons per minute to an average vertical height of 382 feet. No. 11 engine averages 6·27 strokes per minute, and delivers 267 gallons each stroke, equal to 1,674 gallons per minute, to a vertical height of 550 feet. The average duty of these two engines is about equal.

The following remarks on the different types of engines now at work at these mines are offered for the consideration of the members:—

(1) Engines with geared wheels, pumping-shafts, cranks, etc., where heavy pumping is concerned have been found very unsatisfactory and expensive in working and repairs; the various and severe strains set up in the several working-parts are almost sure to lead to occasional if not frequent breakdowns, and the transmission of power from part to part must occasion loss. The experience gained at these mines is in condemnation of the use of the geared engine for heavy pumping.

(2) The Cornish engine is well adapted to its work, but being only single-acting it cannot do as much work as a similarly sized double-acting engine will do. Its action during the stroke is more irregular and violent than the Hathorn-Davey engine, causing greater shock in the pump, and making it necessary to divide the pump into shorter lifts. The ponderous beam and strong building necessary to carry it occasion greater outlay in erecting this class of plant, and in case of loss of the load in the pit the result is often a very serious breakdown. With these exceptions, and as regards repairs in an ordinary way and the matter of duty, the engine does not appear to be inferior to any other type of engine.

(3) The Hathorn-Davey engine is double-acting, and therefore a much smaller engine of this type will do the same amount of work as that done by the larger single-acting Cornish engine. In addition to this, it allows of two rams being used, which discharge into the same delivery-pipe; there is also less shock in the pumps, owing to the more uniform speed during the stroke: consequently longer lifts can be used, which means fewer clack-boxes, rams, stuffing-boxes and glands, and these lessen the first outlay and also the cost in working, and a much cheaper building can also be used to house the engine. There is further the fact

that loss of load in the pump does no damage to the engine, and this has been proved at the No. 10 pit Hathorn-Davey engine on several occasions. This engine has been at work nearly 19 years, and the piston has never been known to strike the cylinder-end. The valve-arrangements on the No. 11 pit Hathorn-Davey engine, which are of the double-beat Cornish type, do not govern the engine as perfectly as the the ordinary slide-valves on the No. 10 pit Hathorn-Davey engine. In putting down this type of engine, it has been found that it is very important that the connecting-rods, bell-cranks, gudgeons and bearings be made of the very best materials and of ample size, otherwise a great deal of trouble and expense will be incurred in renewing and strengthening them.

Referring now to the class of pump—ordinary plunger or ram-pumps attached to heavy spear-rods connected to the bell-cranks of the horizontal engine or beam of the Cornish engine, as the case may be, are almost exclusively used. In the smaller pumps, the clack-boxes are placed immediately under the delivery-pipe, and they are furnished with side-doors and hinged flap-clacks, leather "geared" or "grathed." For the larger pumps, chambers are opened in the sides of the shaft for the clack-boxes, which are furnished with heavy top-covers and double-beat valves geared with strips of guttapercha, set on edge in dovetailed grooves cut in the face of the beat of both seating and crown of valve. The drawings supplied show the arrangement of pumps as fixed in the pit (Figs. 1 and 2, Plate VIII.), and also the details of the valves used in connexion with the 20 inches ram-pumps (Fig. 3, Plate VIII.).

For the Cornish engines, the lengths of lift vary from 240 to 360 feet, but it is found that the shorter lifts are much better in working and are not so troublesome as regards keeping the joints tight and maintaining the glands in good order. With the Hathorn-Davey engine, there is no trouble with blown-out joints in the pumps, although the lifts are over 378 feet in vertical height: they work without shock, and the glands will last for 2 years without repacking.

It has been found that it is desirable that all foundations for heavy permanent pumps should be built on solid rock or cement concrete, and where girders are used that they should be made of wrought iron or steel and never of timber, as with timber it is almost impossible to avoid springing, and thereby causing broken joints and sometimes pipes.

The cost of pumping at these mines averages 1¼d. per 1,000 gallons pumped. This is not considered high, having regard to the price paid for fuel owing to the distance of the mines from the coal-fields. The duty of the engines is not set forth, as this depends so largely on the kind of fuel used, the temperature of the feed-water, the efficiency of the feed-water heaters, and other conditions which in this brief paper it is difficult to mention in detail. What is more especially aimed at is to set before the members of the Institute, on their visit to this district, the extraordinary quantity of water that has to be dealt with and the means employed to cope with it, and to invite discussion thereon.

The CHAIRMAN (Mr. J. L. Hedley) said that the members, on their visit to the mines described in the paper, would be interested in seeing what was being done. He (Mr. Hedley) had seen all the pumping-plant, and he knew how much trouble Mr. Davison had taken over the pumps in times past, and he probably looked upon them almost as his own children. He did not know whether pumps had elsewhere worked for a month under water, but it would be interesting to see what the pump was like, if it was still in existence.

Mr. G. SCOULAR (Whitehaven) said with respect to Mr. Davison's statement about one of the Hathorn-Davey engines stopping when the load in the pit had been lost, he had had a somewhat similar experience, but the engine, in his case, had not behaved quite so well. The differential gear was, no doubt, a very excellent one, but it was altogether too much to expect that it would act in time to prevent disaster in the event, say, of the pump-rods breaking. He had found it necessary to place buffer-beams in the pit strong enough to arrest the weight of the falling-rods, and he would like to know how Mr. Davison had overcome the difficulty. He would also be glad to know if Mr. Davison had found it necessary to place safety or relief-valves upon his clack-boxes. His (Mr. Scoular's) experience had been that spring-loaded relief-valves were a great protection to the castings. When from any cause, such as the pumps drawing upon air, the ram came down with a shock upon the water, the intense pressure which would thus suddenly accumulate is relieved by the instantaneous action of the spring-loaded relief-valve and a probable splitting up of some of the castings averted. Mr. Davison's cost of pumping was very low, and no doubt much of this economy was due to the efficiency of the feedwater-heaters to which he had referred in his paper. He (Mr. Scoular) would like to know if the exhaust-steam passed through the feedwater-heater on its way from the cylinder to the condenser. With respect to the system of pumping, namely, with large

Mines "etc.

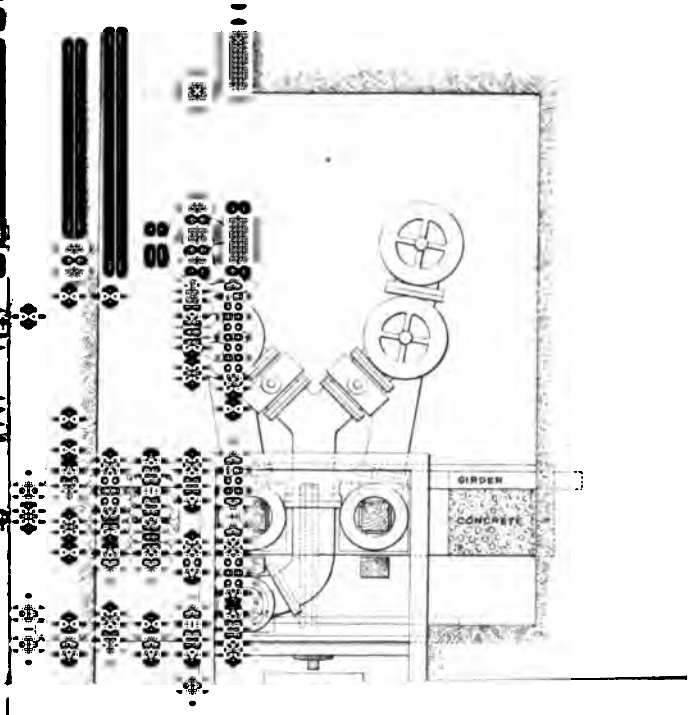

GIRDER
CONCRETE

FIG. 2.—PLAN.

steam-engines encumbering the mouth of the shaft and ponderous pump-rods conveying the power to the pumps, he would like to hear what some of their electrical engineering members had to say on the subject. A dynamo placed in some convenient situation on the surface, driven by a comparatively small high-speed steam-engine or other available means, a cable conveying the power to the underground motor-driven pumps would seem, in many respects, to be an improvement. There was, however, the almost always threatening danger of drowning the underground pump, and he feared there would be some difficulty in working an electric pump for a month under water, a feat which Mr. Davison had accomplished with the existing type of pump at the Stank mine.

Mr. Cedric Vaughan (Millom) said, with reference to the gearing or grathing of valves, that it was found at Hodbarrow that when the gearing was set on the seat of the valve it did not last so well as when it was set on the crown. The reason for the change was that when the gearing was on the seat it was found when pumping sand-and-water that the gearing was beaten out of shape in from 24 to 36 hours; they noticed that in valves of the butterfly type, with the gearing on the top, the valves lasted a much longer time, and it occurred to him that the gearing in the double-beat valve might be transferred to the crown. Accordingly that was done, and since the change the same valve would pump sand-and-water for a week, whereas previously it would not pump for over 36 hours without being beaten out of shape. He would like to ask whether Mr. Davison found that occur in his case, and whether the gearing on the seat of the valve was punished in the same way. It was the first time he had heard of gearing on both seat and crown, and he would like to know Mr. Davison's experience as to how long the gearing lasted. Leather was used for the gearing.

Mr. H. Ayton (Newcastle-upon-Tyne) said that in pumping with a Cornish engine at Wallsend colliery there had been two breakdowns, caused by the losing of the load, and in both cases the piston was broken. Since then a controlling engine had been erected, but when the load was lost a second time the piston was again damaged. They did not pump so large a quantity of water at Wallsend collieries as that described by Mr. Davison, although the engines were capable of pumping 4,000 gallons per minute. Husband valves were used with four faces, the object being not to allow the valves to rise too far. The four faces were lifted simultaneously, and a sufficient quantity of water was released to run through all the faces. The bottom part of the valve was lined with white metal, which could be run in and turned down at small cost. Even when pumping sand-and-water the valve acted efficiently, but the pumping-engine did not work so economically as he would like.

Mr. G. S. CORLETT (Wigan) said that he had erected electric-driven machinery to deal with volumes of about 1,000 gallons per minute, and he was not aware of anything like 4,000 gallons per minute being dealt with electrically at any one installation in this country. He did not think that anyone had yet constructed electric motors of the size that would be required, and which could be satisfactorily operated under water. It was possible to build electric motors to produce from 10 to 50 horsepower, which would run satisfactorily under water ; but he did not think anyone had attempted to build motors of sufficient size which it would be safe to run under water. He hoped to have the opportunity of looking at the pumping-plant in detail, because he did not think that the question of electricity, as applied to such installations, had been very carefully considered by mining engineers, and he was inclined to think that they would be largely guided by what might be termed their previous experience. They knew what a steam-plant could do, but they did not know what an electrical one could. He did not know of any motors which had been running for any length of time under water, but he was at present running an enclosed and hermetically sealed motor—at full load—which had not been opened for a month. It would be quite feasible to run such a motor under water, as water afforded a ready means of dissipitating the heat.

Mr. J. S. JEANS (London) said that Mr. Davison stated that it had been found desirable that all foundations should be made of wrought-iron or steel girders. He would like to know how far iron and steel girders had superseded timber in this district for various purposes, and whether there was any general movement for the superseding of timber in the future.

Mr. J. DAVISON, replying to the discussion, said that he could scarcely account for Mr. Scoular's Hathorn-Davey engine, which did not protect itself from striking the end of the cylinder. The load had been lost at the No. 10 pit by the valves sticking, and no accident had occurred. They used buffers at the end of the slide bars, made of india-rubber and oak-timber, and in addition they inserted strong catch-logs in the shaft (6 feet deep by 2 feet wide of solid oak) and wings on the pump-rods, which in the case of the engine over-going the stroke, took the weight of the pump-rods, but they had never had a blow from that engine. He could not say the same for the No. 11 pit engine, but the accident was attributable to the gear. When they lost the load suddenly the weight was so great that it was almost impossible to prevent the engine from striking the end of the cylinder.

Berryman feed-water heaters were used, and tended materially to reduce their costs. The discharge-water from the condensers was not used in the boiler, as pit-water was used for condensing, and was not fit for boiler use. Town water was used in the boilers.

With reference to the pump working in water, the plans (Figs. 1 and 2, Plate VIII.) showed the pump and also the pump-rods working below. The water was 90 feet above the bottom of the shaft, and the pumps worked for a month at the rate of 8 strokes per minute, under water, until they came to the conclusion that it was of no use to pump any longer: a diver was then sent down to close the door referred to in his paper.

In Fig. 3 (Plate VIII.) it would be noticed that guttapercha was used in the seating and in the crown as well, as experience with the valve had proved that these were the right positions. The valves supplied by Mr. Davey were geared with strips of leather in the crown of the valve, but this arrangement proved that these were unsatisfactory, and having a large quantity of sand in the water it necessitated their constant renewal. Two strips of guttapercha were then placed in the grooves, and between these split copper pegs were driven into the dove-tail cut in the bottom of the groove. The pins held the guttapercha perfectly tight and it never came out. The bottom of the valve required frequent renewal. In refacing, the valve became too low for the seating and a new bottom part was required. To obviate that loss, he cut grooves, and inserted guttapercha in the same manner as at the top, and valves so fitted had been in use for two years and six months, and were still quite good.

He was unfortunately able to say that they had had serious breakdowns of the Cornish engines, as described by Mr. Ayton, by losing the load at the lift. All the gearing of the No. 2 Cornish pumping-engine had been broken not long ago from the same cause. He had not had any experience of four-faced valves, but with two-faced valves the lift did not exceed 2¼ inches.

At the No. 10 pit, oak-timber foundations were used with a span of 6 feet. There was a brick pillar under the bottom valve, and when the engine was making a forcing lift, these timbers yielded, and the joint gave way at the point x (Fig. 1, Plate VIII.). Of course in condemning the use of timber-beams he only referred to their use in connexion with permanent heavy pumping. In erecting a new pumping-plant he was compelled to use iron girders or steel beams, so as to avoid risk of breakage of joints and pipes.

Mr. H. AYTON sympathized with Mr. Davison in regard to the fractures of the joint indicated. It had been remade on several occasions at the Wallsend collieries. On one occasion, the whole column of pumps had to be raised, so as to allow them to remake that joint. He recommended the use of iron girders made of ship iron of the coarsest obtainable quality, in order that acid mine-water could exert the least possible effect on the girder. The girders used at Wallsend colliery were 5 feet deep and 40 inches wide at the top, and upon them the ram-case was placed, but the greatest difficulty had occurred from the springing of the girders, as Mr. Davison had explained, and the resulting fracture of the H joint.

Mr. J. DAVISON said that he had considerable experience in pumping sand-and-water. Within three weeks of starting the No. 10 pump and the Hathorn-Davey engine, they came across running-sand, and for a week the engine was pumping sand-and-water.

Mr. CEDRIC VAUGHAN asked Mr. Davison whether he had pumped sand-and-water since he used gearing both at the seat and crown of the valve.

Mr. J. DAVISON said that they had pumped sand-and-water, but not in so great a volume.

Mr. CEDRIC VAUGHAN said that the effect of pumping sand-and-water with the gearing on the bottom of the valve was very severe.

Mr. J. DAVISON said that he used guttapercha and found that the sand became bedded in it, making it almost as hard as iron, and it lasted a very long time.

The CHAIRMAN proposed a vote of thanks to Mr. Davison for his valuable paper, and the resolution was cordially adopted.

The following paper by Mr. C. E. de Rance on "The Geology of Furness" was taken as read :—

THE GEOLOGY OF FURNESS.

By C. E. de Rance, Assoc. Inst. C.E., F.G.S.

Lancashire-over-Sands, or the old Liberty of Furness, is physically part of South Westmoreland, just as the northern part of the latter is physically part of Cumberland, the drainage running respectively north and south from the central watershed of Westmoreland to the sea, through the two counties named.

The Furness boundary of the county of Lancashire follows valleys for the most part:—the Duddon to the west, Langdale valley to the north, the west side of Windermere to opposite Bowness, where it crosses the lake, and then the watershed, and follows a tributary stream of the river Kent to the south-east.

The district is drained by the Leven on its eastern side, which, out of an area of 202 square miles, contains 190 square miles of Silurian rocks, 10 square miles of Carboniferous Limestone, and 2 square miles of Hawcoat Sandstone.

The Ordnance Survey Catchment-basin map, prepared for the Duke of Richmond's Royal Commission on London Water-supply in 1867, and subsequently published separately by the Survey, includes in this basin of the Leven the small stream draining the Cartmel Valley, the Carboniferous Limestone district of Grange terminating to the north by a north-west fault, ranging to Newby Bridge. To the west, it thins out on the Bannisdale Slates, along a line ranging from Cark to Cartmel. The former place is on the Hawcoat Sandstone, extending to Flockburgh, where it rests on the Carboniferous Limestone. Between Holker and Ulverston, the river Leven occupies a broad flat valley, in which are mounds and patches of Carboniferous Limestone.

Following the left bank of the river Leven from its mouth, Windermere Lake is reached; it is 10⅝ miles in length, and lies in a valley, excavated by the agency of running water; over the portion of the valley, concealed by the waters of the lake, is a rock-basin, excavated below the level of the outfall of the lake at Newby Bridge, and due to the erosive action of glaciers during the Glacial period. Whilst employed on the Government Geological Survey of a portion of the Lake District, the writer sounded the lake, and found its deepest part to be opposite Wray Castle, on the western shore, where a depth of 39 fathoms, or 234 feet, was obtained, a depth greater than that of the English Channel between Folkestone and Boulogne. The surface water of the lake is 134 feet above Ordnance datum (mean sea-level), and the bottom of the lake is consequently 100 feet beneath, being a true rock-basin, the foot of the lake being 0·2 of a foot below the head, and the overflow running away in a river-cut slot. The analysis of Windermere waters by the Rivers Pollution Commission gives only 4 degrees of hardness, and only 2·4 degrees of permanent hardness. The upper portion of the lake has a clear rock bottom, and glacial groovings may be often noticed near Brathay, through its clear waters. At Bowness, the bottom of the lake is filled with fine white felspathic mud, or kaolin, resembling the material that might be expected if old china-plates were put through a pug-mill. The late Dr. Miller, F.L.S., found growing on this the quillwort (*Isoetes lacustris*, L.) The habitat of this plant is the bottom of alpine and subalpine lakes from North Wales to North Siberia, and marks a survival of the Arctic flora introduced by the Glacial episode in Furness.

It is worthy of note, that the representative of the subgenus of the salmon family living in Windermere, known as the charr or *Salvelini*, or *Salmo Willughbii* (Günther), also occurs in Cumberland lakes, at Loch Bruiach in Scotland, and is closely allied to *S. Colii* (Günther) from the Irish loughs and the Eske, all of which are glaciated countries, and point to their survival, on the retreat of the ice, at the close of the Glacial episode.

Just at the county-boundary, the river Brathay is seen cutting a gorge in the Lower Volcanic Series at Skelwith Force, and following that river up to its source the sections of that series are disclosed to perfection under the wild and barren Wetherlam. A minor watershed divides the water of the Leven from its tributary, the range passing through the latter hill, north-east to Low Fell, thence across the Tilberthwaite "col," over Oxen Fells across the "col," through which is carried the coach-road, between Ambleside and Coniston, at a height of 1,056 feet.

The Skiddaw Slates, the oldest rocks in the north-west of England, of Cambrian age, consisting of shales and mudstones, were named by Jonathan Otley, after their uprise at Skiddaw. They indicate a passage from submarine volcanic conditions to those of terrestrial and wholly subaerial volcanoes.* Though forming the mountain of Black Combe, in Cumberland, so salient an object to the north-west, from a long coast line in Lancashire, they do not cross the Duddon, and are consequently not present at all in Lancashire. They are supposed to represent the Tremadoc Slate Series and *Lingula*-flags of Wales.

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* Rev. J. Clifton Ward, *Geological Magazine*, 1879, new series, decade II., vol. vi., page 49; also "Geology of the Northern Part of the English Lake District," *Memoirs of the Geological Survey of England and Wales*, 1876.

Overlying these rocks in northern Lancashire are "the Volcanic Series of Borrowdale," so named by Messrs. Harkness and Nicholson in 1872, which were previously known as the "Green Slates and Porphyries" of Messrs. Otley and Sedgwick. They can be nowhere better studied than in the belt of country lying in North Lancashire, between Brathay on the shore of Windermere, where they are overlain by the Coniston Limestone series, to Yewdale, north of Coniston, the outcrop of the latter being well marked by the old lime-kilns, set up for the purpose of producing agricultural lime, before the introduction of railways, and the entrance of lime from other counties.

The uppermost stratum of the volcanic series is a massive breccia, and extends over a wide area; beneath it are the Tilberthwaite Slates, which furnished the covering of St. James's and Kensington Palaces and many of the earlier London mansions. They are thicker than the North Wales slates, and are remarkable for the beautiful stripes of the component beds and the minute faulting that they have undergone, which is generally "reversed." The writer called the attention of Mr. J. J. H. Teall, F.R.S., to them in 1884, and he described one in the *Geological Magazine.** The writer has deposited several of them in the Museum of Practical Geology, Jermyn Street, London. In these measures the copper-bearing rocks of Coniston occur, which have been worked probably since the time of the Romans. At the entrance of the Tilberthwaite valley from Yewdale, the writer discovered some years ago visible gold in a blende vein, which was most favourably spoken of by the late Sir Andrew Ramsay, F.R.S., the late Sir Warington Smyth, F.R.S., the late Professor Morris, F.G.S., and the late Mr. John A. Phillips, F.R.S., but owing to the experience at that time happening on the Duke of Sutherland's estate in the north, the writer did not disclose the site. He thinks it advisable, however, to record the general fact, as processes now in existence may render what was useless a quarter of a century ago a commercial success at the present time.

In the Furness portion of the English Lake District the sequence of Silurian rocks is as follows, in descending order:—

The Kirkby Moor Flags, 1,000 feet thick.

The Bannisdale Slates, of no commercial value, 5,000 feet thick.

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* 1884, new series, decade III., vol. i., page 1.

The Coniston Grits, so named by Prof. Sedgwick from Coniston in Lancashire, where they are well exposed, 4,000 feet thick.

The Coniston Flags (Brathay Flags, of Prof. Sedgwick) are fairly cleaved, and form good flags at Brathay quarries, near the head of Windermere ; they are over 2,000 feet thick.

Stockdale Shales, so termed by Mr. W. T. Aveline from their occurrence at that place near Windermere ; they average 200 feet, but are very variable ; in North Wales they are the Tarannon Shales.

Graptolitic Mudstones—they were so named by Prof. Harkness in 1868—are 40 feet thick and well seen at Skel Gill near Ambleside, and at Appletreeworth Beck, near Yewdale, Coniston ; at the latter place they rest on the Coniston Limestone, with a calcareous gritty base.

Ashgill Shales, so named from Ashgill, 3 miles south-west of Coniston, are 200 feet thick, and pass into the grey crystalline Coniston Limestone, which, with its associated shales, reaches another 200 feet. These beds form the uppermost member of the Lower Silurian system in this district, there being an unconformity at the top, as pointed out by Prof. Hughes, in this immediate area. The late Mr. John Bolton of Ulverston pointed out that the Coniston Limestone * was formerly used for cement and agricultural purposes, and was the first to note the occurrence of hæmatite in it at Millom.

Mr. W. T. Aveline was the first to point out that there is an unconformity between the Coniston Series and the Borrowdale Volcanic Series below it so far back as 1872.† The late Prof. Phillips stated that the superior hardness of the rocks forming the Borrowdale Series was the cause of the picturesque mountains of the Lake District, and the variety of their outline. These, for the most part, are beyond the Furness boundary, but are the visible frame to that area looking northward.

The Carboniferous Limestone plays an important part in the scenery at Grange and Cartmel, and a still more important part commercially in the district lying between the Duddon and Ulverstone, in yielding the extensive deposits of hæmatite-ores.

Miss E. Hodgson, in 1864, in a memoir "On the Glacial Drift of Furness, Lancashire,"‡ pointed out the extreme solubility of the limestone, when remaining long in contact with moisture ; and in 1867, published an interesting paper on "The Moulded Limestones of Fur-

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* *Geological Fragments collected principally from Rambles among the Rocks of Furness and Cartmell*, page 49.

† *Geological Magazine*, vol. ix., page 441.

‡ *The Geologist*, London, 1864, page 209.

ness,"* in which she describes the Carboniferous Limestone as flanking the Silurians, in a band 10 miles in length, in the Furness area, and from 1 to 5 miles in width, extending to the seacoast, and rising to 446 feet at Birk Rigg Common. She suggests that, as the beds dip seawards, at an angle of 9 degrees to the south-east, they may form a part of the floor of Morecambe Bay. A representation† is given of the moulded and indented limestone, 7 to 15 feet of pinnacles and clefts, the latter going down into the "rotten-rock" of the quarry-men, overlying the compact limestone suitable for building-stone, at Tarn Close Quarry, 1 mile north-west of Ulverston, where the rock is over 60 feet thick, notwithstanding that it is only 300 feet from its junction with the slate. She points out that the percolation of waters charged with humus, as first suggested by Prof. Liebig, is a potent cause of disintegration, the ordinary action of frost and lichens at the surface, and of circulating absorbed rainfall in fissures, this latter cause must have an important influence on the distribution of iron in pot-holes and fissurse.

It is probable that the Windermere united glaciers did not follow the present outfall stream between Yewbarrow and Backbarrow and the Leven, but passed over the flat tract connected by a "col" with Ayside Pool valley, flowing through Cartmel to the sea at Cark.

The river Crake, falling into the tidal portion of the Leven, may be regarded as a separate stream ; it drains the valley in which occurs the rock-basin, known as Coniston Lake, the surface of which is 147 feet above mean sea-level, with a depth of 160 feet, or 13 feet below sea-level, while its surface is 13 feet above that of the surface of Windermere. Above the lake rises Coniston Old Man, to a height of 2,633 feet, being the highest point in Lancashire, beneath which is Levens Water, 1,350 feet above the sea, and the copper-mines are drained by Church Beck, which discharges milky water into Coniston Lake.

Westward of the Crake basin is that of the Duddon, the left bank of which alone is in Lancashire, and forms the boundary of the Liberty of Furness, of which the manor of Ulverston forms a part. The name first appears in the foundation-charter of Furness Abbey, bearing date 1126, where it is Latinized into "Fudernesia," pointing to its derivation from the "further ness" or promontory as against "Amounderness," the tract lying south of Morecambe Bay, between the Lune and the Ribble. At one period, the Furness Fells formed the boundary between England and Scotland, and so late as 1138 the Scots turned the peninsula into a desert.

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* *Geological Magazine*, 1867, vol. iv., page 401. † *Ibid.*, page 403.

while Mr. Aveline, whose opinion is of great value from his wide and varied experience, still supports the views of his former colleague, Sir Roderick Murchison, as already stated.

Whatever difference of opinion there may be as to the age of the rocks above the Magnesian zone, this does not apply to those below it.

Sir Roderick Murchison (*loc. cit.*) gave an early description of the Permian "crab-rock" at Park, from about 1½ to 2 miles north of Furness Station, on the Furness Railway—angular fragments of Carboniferous Limestone, cemented above but interspaces below, resting on the solid limestone below, the breccia being locally known as the "crab rock." It is well seen at St. Helens, ½ mile to the north of the Park cutting, immediately east of the railway, and also at Dalton. Sir Roderick Murchison points out that joints, fissures, and caverns were formed before the era of the crab-rock, and became subsequently filled with hæmatite, an opinion formed by Prof. Phillips as far back as 1857.* The crab-rock, as pointed out by the late Prof. Henry Alleyne Nicholson,† is overlain at the village of Stank by Middle Permian yellow Magnesian Limestone, consequently the infilling of the iron is of Permian, or pre-Permian, age.

As regards the iron-ores, both of the Coniston and Carboniferous Limestones of the Furness district, Mr. J. D. Kendall, F.G.S., M.E., has adduced such a mass of material in his work on the *Iron-ores of Great Britain and Ireland*,‡ and in various papers published in the *Transactions* of various scientific societies, that the writer feels there is no need to refer to this portion of the subject, as all must realize that Mr. J. D. Kendall has collected a wonderful mass of facts, whether all the conclusions he draws from them are agreed to or not.

This communication has been suggested to the writer as being possibly useful to members attending the general meeting. He has had the advantage of knowing the district for over 30 years, and being officially connected with it on behalf of the Geological Survey, and of meeting many of the original observers, amongst others the late Sir Roderick Murchison, the late Prof. Harkness, the late Mr. Binney, F.R.S., the late Mr. Bolton of Ulverston, and Mr. Talbot Aveline, who is still present with us to write the last published communication on the geological aspect of Furness. The writer hopes that this paper will be taken as an introduction to that just issued on "The Occurrences of Anhydrite in the North of England."*

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* *Report of the Twenty-eighth Meeting of the British Association, Leeds*, 1858. Transactions of the Sections, page 106.

† *Essay on the Geology of Cumberland and Westmoreland.* London: Robert Hardwicke, 1868, page 92.

‡ London, Crosby Lockwood & Son, 1893.

The **Chairman** moved a vote of thanks to C. E. de Rance for his valuable paper, and the motion was cordially adopted.

Mr. G. **Scoular** proposed a vote of thanks to the owners of mines and works to be visited, and also to the Furness Railway Company for the arrangements which had been made for the transport of the members during the meeting.

The **Chairman** seconded the motion, which was carried with acclamation.

Mr. C. **Vaughan** moved a vote of thanks to Mr. Hedley for presiding, and the motion was cordially adopted.

The following notes record some of the features of interest seen by the visitors to mines and works, etc., which were, by kind permission of the owners, open for inspection during the course of the Furness meeting on July 12th and 13th, 1899 :—

HODBARROW IRON-ORE MINES.

The mines were first discovered by the occurrence of veins of ore on the shore. The late Earl of Lonsdale worked one of the veins at Towsey Hole. He eventually gave up the venture, and granted a take note to the founders of the Hodbarrow Mining Company, Limited, in 1855.

A shaft was sunk on the same vein, and the shaft and engine-house were still visible. As the vein was followed it began to nip out, and boring became necessary. The late Mr. Wm. Barratt observed that the veins were converging towards the west, and put down a bore-hole into 100 feet of solid ore, and so discovered the present mine in 1856. This deposit produced excellent ore, and while the company were working this mine workmen's houses were built without knowing what was beneath them. While sinking a well to supply these houses with water, another large deposit was found by means of a bore-hole, put down at the bottom of the well with the view of increasing the water supply. Afterwards other bore-holes were put down, and it was found that there was a very large deposit of ore.

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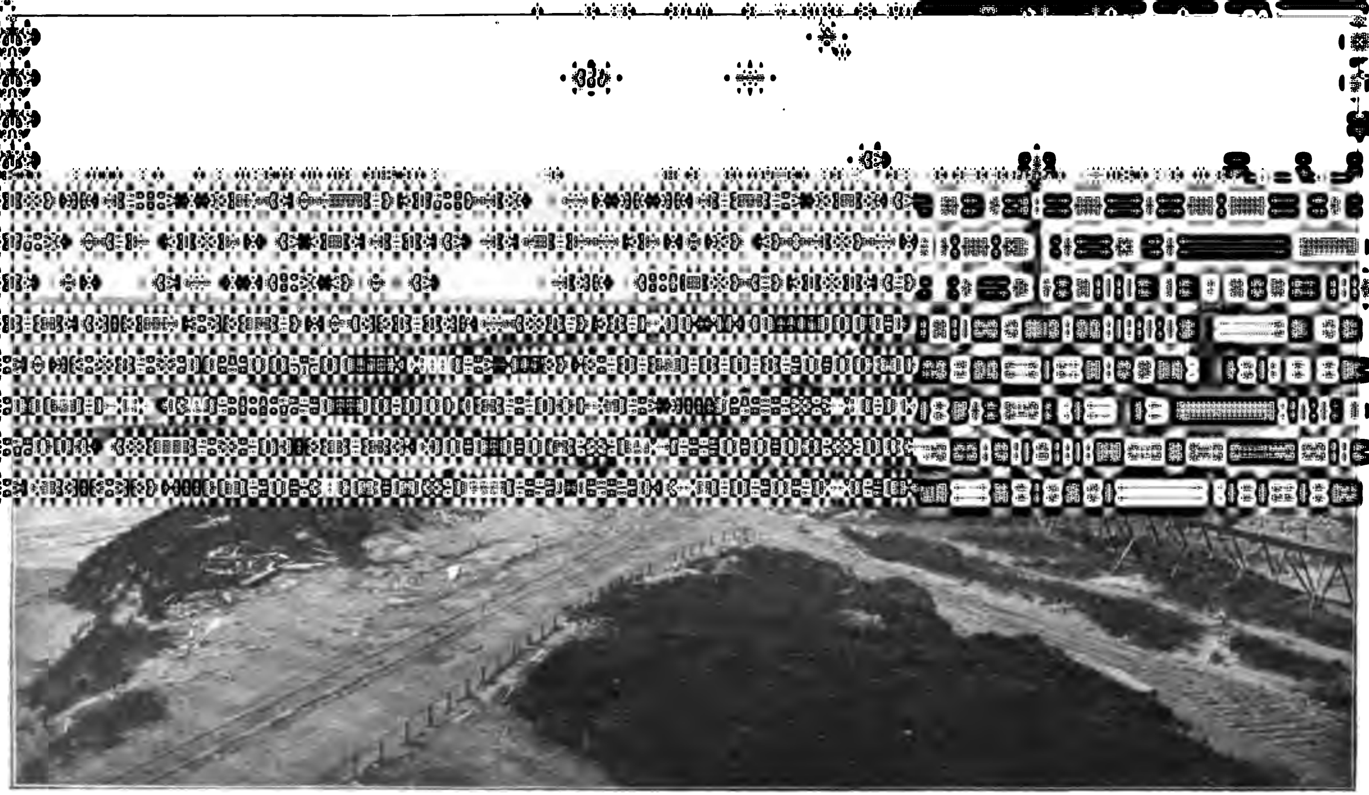
* *Trans. Inst. M.E.*, vol. xvii., page 75.

The first-discovered deposit was comparatively shallow, with not more than 60 feet of cover over it at any part, and in one place it came almost to the surface. The second deposit was also a good one, and it overlapped the third deposit, which was much larger and considerably deeper, the cover being about 200 feet thick. The longest section of uninterrupted ore-ground occurred in a north-and-south line. At the northern end the ore-deposit abutted against Carboniferous Limestone, and was covered with sand and clay, until it ran under the sea-wall and out to sea.

Before the sea-wall was erected, a barrier of ore, 360 feet wide, was left along high-water mark so as to protect the mines from the sea, the deposit being worked on the system of caving-in (by which the ground was allowed to fall in after the ore was removed). It was recognized that a large quantity of ore was left to protect the mines from the sea. At that time the sea was encroaching on the sandbanks, and timber revetments were erected to protect the ground from the sea. The first sea-wall was built for the purpose of working this belt of ore 360 feet wide, and it had answered its purpose admirably. Sir John Coode was the engineer, and it was his last work, for he finished it just before he died. It was a novel piece of engineering, being a combination of a wall and a water-tight dam.

The wall was made of concrete in mass, and it was carried down to a bed of clay varying from 18 to 22 feet below the surface of the shore. Inside the wall was a bank of puddled clay which was pinned down into the clay below the bottom of the wall. In addition, a row of pitch-pine sheeting (12 inches square) was driven down 6 or 7 feet below the bottom of the concrete wall, so that the sea was absolutely cut off, and if any water by chance got through the sheeting, it was cut off by the puddled clay and trench. The sea-wall was supported by the backing of clay and a timber revetment, the latter of which, however, had not proved of much use. The idea was that if any water came over in a high storm it would fall on the asphalt pavement and be stopped by this revetment, scuppers being provided for returning this water into the sea. By means of the sea-wall they had been able to practically take out the whole of the ore within its area.

While this working was proceeding, borings were made beyond the sea-wall, and they proved the seaward extension of the ore at depths varying from 13 to 109 feet. It was sufficiently proved that there was a large seaward deposit of ore, but the extent of the ore-ground had not yet been fully proved. The new scheme proposed the erection of another sea-wall, which would exclude the sea from a larger area. It



View of the Sea-wall at the Hodbarrow Iron-ore Mines.

might be thought rather foolish perhaps to decide finally upon such a scheme before one knew how far the ore extended, but there were reasons why it would not be wise to enclose a larger portion than that contemplated. The most important consideration was navigation, and nothing could be allowed which would imperil the navigation of the Duddon estuary.

As the ore went seaward it passed under a limestone roof, which began about the line of the existing sea-wall like the thin edge of a wedge, and it increased in thickness seaward until it became over 100 feet thick. Consequently, if the ore did extend beyond the second sea-wall it would be possible to work it out beyond the barrier with so thick a roof of limestone.

The second sea-wall, when it was made, would enclose an area of about 170 acres. The mode of construction would not be the same as the old wall, as a more flexible structure would be less liable to fracture under certain circumstances. It was proposed to form a main bank of limestone rubble, faced with blocks of concrete pitched pell mell so as to break the force of the sea; there would be an inner and smaller embankment of slag or limestone; and the spaces between the two walls would be filled with clay. In order to make the structure watertight a bank of clay-puddle would be placed in the middle and carried to a height of several feet above high-water mark of ordinary spring tides. The puddled clay would also be protected by sheet-piling driven sufficiently deep so as to prevent water percolating below it. It was stated that such a dam would be completely watertight during the time that the tide was up. As the tide was intermittent, the pressure of water had only to be resisted for a certain number of hours during each day, and although it might not be watertight against a constant pressure it would be so against the intermittent pressure of the tides.

About 12 months ago, while working the ore-ground on the western side of the mine, a run of sand came into the mine, and as runs of sand had previously occurred northward, no special precautions were deemed necessary. However, one morning the shore—outside the sea-wall—caved in, and there was a clean run of sea-water under the sea-wall into the mine. Fortunately it was found out almost as soon as it occurred, the hole was filled with gorse and clay, and the rush of water was checked. Although the ground continued to cave in all round the original depression until almost an acre of ground had subsided, the depression was filled up and made perfectly watertight. The most alarming feature was that the wall began to crack owing to undermining;

but fortunately the process of filling up went on sufficiently fast, and the subsidence was arrested: all that had happened was the formation of a crack in the sea-wall. Messrs. Coode, Son & Matthews, the successors of Sir John Coode—the engineer who built the wall—advised that it would stand sufficiently well if it were not exposed to shocks from the sea, and in order to prevent that occurrence blocks of concrete were thrown out so as to protect the wall from the sea. A large quantity of clay was also tipped inside the sea-wall, so as to make it quite safe, and the influx of water had been stopped.

Owing to this accident, the new structure would be placed as far seaward as possible, so that if ever similar runs of sand were encountered there would only be the enclosed area to contend with.

Under the pinnel, where there was no limestone, the caving-in system of mining was adopted; but under the limestone-roof the American system of mining and timbering would be adopted. The American system of timbering had been tried experimentally in other parts of the mine and found to answer admirably, except that it would not withstand side drag; but in the virgin ground beyond the first sea-wall it should prove very satisfactory. There was little doubt, however, that the limestone-roof originally extended all over the deposit, and that the limestone had been denuded over the northern portion by glacial action. At the Red Hills quarry, the upper surface of the limestone was deeply scored with glacial marks, and was ground perfectly smooth. At Hodbarrow point the surface of the limestone was polished perfectly smooth, and the glacial striæ all pointed in one direction. There could be no doubt that the great ice-sheet had stripped the limestone off the ore, leaving it exposed over the northern area, and carrying away a certain portion of ore with it. This was clearly indicated by the fact that the overlying pinnel or Boulder Clay was deeply stained with ore.

A solid pillar of ore would be left under the point of the limestone-roof, and the American system of mining and timbering would begin seaward of that line. This barrier would keep the timbering apart from the drag of the old mine.

The bore-holes south of the present sea-wall had passed through the iron-ore into limestone and thence into conglomerate, the lowest member of the Old Red Sandstone. This occurrence was interesting, as it pointed to the removal or absence of the strata intervening between the Carboniferous Limestone and the Old Red Sandstone. Possibly it may have been removed by a previous ice-age, as Sir Robert Ball suggested that ice-ages recurred at intervals of 25,000 years.

The members also visited the Red Hills limestone quarry of the Millom and Askam Hæmatite Iron Company, Limited; the steel-works, Park, Stank and Yarlside iron-ore mines of the Barrow Hæmatite Steel Company, Limited;[*] and the Roanhead iron-ore mines and colour-works of Messrs Kennedy Brothers.

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[*] *Iron and Coal Trades Review*, 1899, vol. lix., page 205.

THE INSTITUTION OF MINING ENGINEERS.

GENERAL MEETING,
HELD IN THE ROOMS OF THE GEOLOGICAL SOCIETY, BURLINGTON HOUSE, LONDON, MAY 25TH, 1899.

MR. J. A. LONGDEN, PRESIDENT, IN THE CHAIR.

PRIZES.

The **SECRETARY** announced that the Council had awarded prizes of books to the writers of the following papers, which had been published in volumes xiv. and xv. of the *Transactions* :—

"The Strength of Pit-props." By Prof. Henry Louis.
"Electric Blasting." By Mr. Wm. Maurice.

The **PRESIDENT** (Mr. J. A. Longden) delivered his presidential address as follows :—

PRESIDENTIAL ADDRESS.

BY J. A. LONGDEN.

I am deeply grateful to my fellow mining engineers for the mark of appreciation that they have exhibited in electing me to be their President for the present year. It is 36 years since I began the study of the various branches of knowledge more particularly embraced in the profession to which we belong, and during the whole of that time my thoughts and attention have been devoted to the subject. I yield, therefore, to none in my interest in The Institution of Mining Engineers, and trust that at the close of my year of office I may be able to hand to my successor the Presidency of this society in an increasingly useful condition.

I have looked through the presidential addresses since The Institution of Mining Engineers was initiated in 1889, and have been struck with the absence of similarity of thought which exists. We know that mining engineering as now practised includes a wider range of subjects than any other profession, and hence the probable cause of divergence of thought in the various utterances : at the same time, it is evident that the longer we live as an Institution the more the presidents must overlap in their remarks.

The thought that has impressed my mind lately is the rapid exhaustion of our coal-fields. In 1615, 400 ships were employed in the Newcastle coal-trade ; and keels or barges, pushed down stream by heavy poles, took the coal from the waggons to the ships which were anchored in deep water.

Early in the seventeenth century, one coal merchant employed from 500 to 1,000 men, yet we are told that this merchant "for all his labour, care and cost, could scarce live off his trade; many others have consumed great estates, and died beggars." One gentleman from the south invested £30,000 in mines; he bought new engines to drain the pits, and invented boring with iron rods to discover the thickness of the seams, but he did not reap any reward: he spent his money, "and rode home on a light horse."

London became so dependent on the Northern coal-field that in the troubles of 1745, General Wade fixed his head-quarters at Newcastle-upon-Tyne to prevent the coal-pits from falling into the hands of the Pretender. So writes Bishop Creighton in his *Stories of some English Shires*, a description of what took place only 154 years ago, not long in the life of a nation.

During the last 25 years, the output of coal has increased from 120,000,000 to 200,000,000 tons, and the ratio of increase (after deducting years in which great strikes occurred in the coal-trade) is 2½ per cent. per annum. If we divide the 25 years into two parts, we find that the rate of increase was 3 per cent. in the former and 2 per cent. in the latter part ; and we may fairly assume that, during the next 25 years, the increase, notwithstanding growth of population, will not be more than 1½ per cent. per annum on the average and probably less. Consequently, in the year 1925, the output should not exceed 280,000,000 tons. When we look at the coal-fields of Great Britain, we can see counties the best of whose coal will be exhausted by that time. Very few royalties of any magnitude are unlet, and the question arises from whence is this additional 80,000,000 tons to be derived, beyond what we are now working? The answer of those who have not studied the question is, let us go deeper, but, unfortunately, when we reach the Millstone Grit we have touched the bottom, and very many collieries are in that position now.

It is a wellknown fact that the deeper we go the greater is the cost of getting coal, in consequence of the much larger quantity of timber necessary to support the additional thickness of cover, and the roof itself is of a more disintegrated nature causing the roads to be more costly to maintain.

I have merely suggested 25 years, but that is not long, and 50 years is nothing in the life of a nation. One of the great ironmasters has stated that there will be no blast-furnaces at work in the Middlesbrough district in 50 years' time. Recently, one of the large firms in the Cleveland district has been converted into a limited company, and it was stated that their mineral resources will be exhausted in 40 years.

At the present time, good pig-iron can be made in the United States of America for 35s. per ton – in this country it costs 45s. to make as good a quality. The question naturally arises, how can the ironmaster live if he has to buy ore from Sweden and pay double the price that he has recently paid for coke? To this, there is only one answer, namely, wages must suffer, or we must lose our trade. In the Midland mines-inspection district there are 1,500 men less employed last year (out of 80,000) than the year before. This is no doubt due to the higher wages paid in that district, as there is an increase in other districts in the United Kingdom of 4,300 men, and this indicates that abnormally high wages drive trade into other quarters.

I do not wish to take a pessimistic view, but Mr. T. Forster Brown (one of our most eminent mining engineers) recently read a paper before the members of the British Association for the Advancement of Science* and more recently before the Society of Arts†, and stated that $\frac{11}{15}$ths of the best of our coal-supply would be exhausted in 50 years. Yet, the leading articles in most of the newspapers the next day suggested that there is enough for us and that the next generation might take care of itself, a remark which, I think, was not dictated by true national spirit. Some 25 years ago Britain supplied 50 per cent. of the world's coal-consumption, and now we only supply 30 per cent.; while 25 years ago the United States of America supplied 15 per cent. of the world's coal-consumption and now they supply 30 per cent.

In 1894, Mr. G. A. Mitchell in his Presidential address‡ to the members of the Mining Institute of Scotland, stated that the average depth in 1874 from which coal was extracted in Scotland was 420 feet, and in 1892 it was 580 feet, or an increase of about 38 per cent. in less than 20 years.

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* *Report of the Sixty-eighth Meeting held at Bristol*, 1898, page 611.

† *Journal*, 1899, vol. xlvii., page 506. ‡ *Trans. Inst. M.E.*, vol. vii., page 330.

The Scottish coal-supply is now chiefly drawn from the Lanarkshire coal field, namely, 16,000,000 out of 30,000,000 tons, or more than one-half of the whole. Mr. R. T. Moore, of Glasgow, computed in 1893 that 668,000,000 tons had already been worked and that 265,000,000 tons were still unworked. Since then, this latter figure has been reduced by over 70,000,000 tons, so now there is less than 200,000,000 tons left to work, and this at the present rate of exhaustion would be depleted in about 12 years. Mr. Moore states that the exhaustion of the upper seams will "finish the cheaply worked coals of Lanarkshire."

In Durham and Northumberland, there is very little unlet coal, and this remark applies with even greater force to Lancashire. In Yorkshire, the best seams of coal will be exhausted in 50 years, and the coal-fields which are unlet will probably cause such a subsidence in the low-lying lands that the damage to the surface through flooding and consequent permanent loss of land for agricultural purposes will prevent them from being worked. In the Midland district, all the profitable mines will be exhausted before 50 years are out. We have therefore South Wales left as a stand-by, and all the best coal there is already leased; and yet, notwithstanding all these facts, nearly 10 per cent. of all the coal got is left in the pits and lost for ever.

I estimate the average thickness of the seams now being worked in this country to be about 5 feet, the average in France is 3 feet 5 inches, and in Belgium 2 feet 2 inches. In this great difference in thickness, we have no doubt one important factor as to the great difference of the wages which the miners receive in the three countries named. In a thin cannel-seam in Yorkshire, a man can only get 1 ton per day as compared with 3 tons per man per day, which is the average of the United Kingdom. This clearly indicates that coals will cost more than twice as much as they do now when thin seams are all that we have to rely upon. A very important point is that thin seams lie mostly between thick seams which have been already worked, in some cases they will be full of water; in nearly all cases they will be broken up, so that the nature will have gone out of the coal; they will be most expensive to work, and the roads will be almost impossible to maintain.

We shall probably export 40,000,000 tons of coal this year to other countries who manufacture at less cost than we do with our cheap fuel, who send their goods over to us duty free, and then undersell us in our own market. I am not prepared to advocate a duty on imported manufactured goods, although I should not object to it, but I cannot see why we should not put a duty of 6d. per ton on all coal exported. Such a tax would tend to keep valuable fuel at home, where we shall undoubtedly want it before long, and it would bring in £1,000,000 per annum, which would give 10s. per week to 40,000 old or disabled miners and thus provide for colliers the old-age pensions of which we hear so much.

The average tonnage of coal got per man in this country is 300, and as we produce 200,000,000 tons yearly we have a mining population of 700,000, and certainly there are not anything like 1 in 20 who are infirm or past work.

All these considerations point to one thing, namely, that in 50 years we shall practically be dependent on the United States of America for cheap coal, iron and steel, and when this comes about we or our sons will find out that an alliance with the United States of America for coaling our navy is imperative. The idea that "the future lies in the employment of explosives as motive power" may be correct, but there is no reason why we should waste the pound of coal we have and which has more than double the energy of an equal weight of dynamite.

Mr. Ruskin says that "God has lent us the earth for our life; it is a great entail, it belongs as much to those who are to come after us and whose names are already written in the book of creation, as to us, and we have no right by anything that we do or neglect, to involve them in unnecessary penalties or deprive them of benefits which it was in our power to bequeath."

Mr. WILLIAM COCHRANE (Newcastle-upon-Tyne) said that he had pleasure in congratulating their President on his address. The attention which Mr. Longden had drawn to the exhaustion of the coal-fields was the chief subject of his own presidential address to The North of England Institute of Mining and Mechanical Engineers.* When he delivered that address, he took the same period of 50 years, but he qualified it considerably by stating that inasmuch as previous calculators had settled that they were perfectly safe for 100 years at least (and some of them much longer), he had stated that in his judgment the exhaustion of the coal-fields would be nearer 50 than 100 years. Some few years had gone by since then, and the President (Mr. Longden), notwithstanding all the discoveries of coal, with which he must be acquainted, in Kent, Lincolnshire, and elsewhere, had arrived at the same figure of 50 years, and he entirely agreed with him.

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* *Trans. Inst. M.E.*, vol. ii., page 181.

At the same time, he thought that engineers should exercise such care in the economy of the coal that they should not leave their successors 50 years hence (or whatever time further developments might enable them to secure trade for their benefit) without supplies. He agreed with the deduction which the President had drawn from the present state of the coal-industry. They ought to be glad that the President had called attention to this subject, considering the large experience that he had had of the different coal districts throughout the country. The members would join him in thanking the President for giving them so very succinct a summary of the conclusions at which he had arrived.

Mr. Henry Lewis (Annesley), in seconding the vote of thanks, said that he had known Mr. Longden for 25 years, and he knew that his conclusions might be relied upon as the result of great experience in the Midland counties and in different parts of the United Kingdom. Although it was a gloomy prospect to look to the exhaustion of our coal-fields in 50 years, he hoped that the thinner seams now left unworked would come into the market.

His Excellency Don Arturo de Marcoartu (Madrid, Spain) wrote that he had read the interesting address of the President of The Institution of Mining Engineers. He was unable to check and to appreciate the figures on the rapid exhaustion of the British coal-fields. But it appeared to him that an evolution of the iron and steel trades was approaching in Great Britain and in his own country, Spain. The price of the production of the coal each day will be enhanced with the increasing depth at which it is worked in Great Britain. At the same time, the price of iron-ore for Bessemer steel, from Sweden or from Spain, will not become much cheaper than it is to-day. Unless the cost of production can be reduced, the selling price in Great Britain of coal will be not less than 8s. per ton, and Spanish iron-ore, with 50 to 54 per cent. of metallic iron, will cost 15s. to 16s. per ton at Middlesbrough. The prices of both coal and iron-ore in the south of Spain are much below these figures. It would be possible to establish blast-furnaces and iron-works in the south of Spain for the production of ingots, rails and many other common iron and steel products, for sale in the Mediterranean, Africa and the East, at lower prices than the produce of British manufacture.

The President (Mr. J. A. Longden), in acknowledging the vote of thanks, said that he did not want to draw a gloomy picture with regard to the coal-trade. Mining engineers were looking forward to the employment of machinery as a means of working thinner seams; but when they came to introduce coal-cutting machinery they would find unforeseen difficulties, and the utilization of coal-cutting machinery in the working of thin seams would not extend the life of the coal-seams of Great Britain so long as some people imagined.

DISCUSSION ON PROF. H. LOUIS' "FURTHER NOTES ON PIT-PROPS."*

Prof. H. Louis (Newcastle-upon-Tyne) said that, since reading this paper, he had had the opportunity of testing some tubular steel-props made by Messrs. Chambers Brothers & Company, of Ilkeston. They consist of 4-feet lengths of weldless steel-tubes, with the ends welded up. The material was a mild steel containing 0·16 per cent. of carbon. The following table shows the results obtained :—

Diameter of Steel-tubes	2¾ Inches.	4 Inches.	4½ Inches.
Test No. 1.—Breaking-weight in tons...	21·40	67·75	69·38
Test No. 2.—Breaking-weight in tons ..	17·97	60·95	62·92
Test No. 3.—Breaking-weight in tons ..	12·90	63·37	64·92
Averages	17·42	64·02	65·74
Average breaking-weight in tons per square inch of end-surface	2·93	5·09	4·13
Average weight of props in pounds ...	18½	46½	50
Average thickness of metal in inches ...	$\frac{3}{16}$	$\frac{9}{32}$	$\frac{9}{32}$

In every case, the props yielded by buckling, the welded ends being generally crushed in also. It was noticeable that the yielding was always very slow and gradual, ample warning being given before the prop collapsed. In this respect, steel tubular props were distinctly superior to any wooden prop.

Mr. J. Emerson Dowson read the following paper on "Metric Weights and Measures" :—

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* *Trans. Inst. M.E.*, vol. xv., page 343; and vol. xvii., page 14.

METRIC WEIGHTS AND MEASURES.*

By J. EMERSON DOWSON, M. Inst. C.E., Chairman of Executive Committee of the Decimal Association.

In the time at the writer's disposal, it will not be possible to treat this important subject exhaustively, and he thinks that he will best consult the wishes of the members if he assumes that they are acquainted with the metric weights and measures, and if he deals more particularly with some of the points which have a bearing on the work of engineers.

Engineers use decimals for many of their calculations, in fact without them they would be seriously inconvenienced; but it is often more convenient to use vulgar fractions also, especially when dealing with halves, thirds and fourths of the smaller numbers. Oddly enough, some of our opponents have got the twisted notion that if the metric system be adopted, we must give up vulgar fractions altogether; in other words, if we use meters, kilograms or liters, we must not say the half or quarter of a meter, kilogram or liter. This is really absurd, and is contrary to what is actually done in the countries where these measures are used. In France for instance, it is common to buy and sell in the markets and shops by the kilo, the livre or half-kilo, and the half-livre. It matters little what the particular name or nickname may be, the essential point is that the value of each is known in terms of the metric system. A kilo represents 1,000 grams, a half-kilo or livre (pound) 500 grams, half a livre 250 grams, and so on. Just in the same way, a 5 centimes copper coin is commonly called a sou, and a 10 centimes coin 2 sous. This is merely the survival of an old name, which is immaterial, but the value of each is understood in centimes, and accounts large and small are made out in francs and centimes, not in sous. For measures of length, there is the meter divided into centimeters and millimeters, and it is equally correct to say 1½ or 1¼ meters, as to say one meter fifty, or one meter twenty-five. When the fractions cannot be expressed shortly in this way, they are usually given in centimeters, or millimeters, whichever happen to be the more convenient. For instance, the thickness of walls, the diameters and thicknesses of pipes, the sizes of shafting, pulleys, valves, etc., are usually given in millimeters. They are written as whole numbers, without any decimal point, and when added together or multiplied, if the total exceeds one meter, it is stated in meters and millimeters. The writer had had a good deal to do with engineering drawings from different countries, and he said deliberately that ordinary calculations were not only more easy in the metric system, but there was less risk of misreading the dimensions than in the case of feet and inches marked with single and double ticks or dashes in the usual way. As an instance, he had before him an elaborate working drawing from one of the leading engineering firms in Germany. There were nearly 200 dimensions figured on it: all were in millimeters, and there was not a single decimal point or comma to be seen, and no possible risk of misreading. At the same time, it was easy to add them together and get the main dimensions in meters and millimeters by a mere stroke of the pen. We have only to compare this with what would have to be done with feet and inches, and fractions of inches, such as quarters, eighths, sixteenths and thirty-seconds, and we see at a glance the much greater simplicity and the superiority of the metric system.

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* The British names of metric weights and measures are adopted in this paper.

Some persons affect to ridicule a decimal system, because of the danger of misplacing the decimal point, and because they suppose it is nearly always necessary to use three or more decimal places for the fractions. This is really a delusion. The difference between a meter and a centimeter or millimeter, or between a kilo and a gram, is much greater than the difference between a foot and an inch, or between a pound and an ounce. This fact alone makes it more easy to avoid mistakes in the metric system than in any other. If a decimal point is misplaced, the error increases or diminishes the number by 10 at least, and this is more noticeable than if feet or inches, or pounds and ounces were misplaced. The writer will give a case in point, from independent testimony. A few years ago, Messrs. Willans & Robinson, the wellknown makers of steam-engines, adopted metric weights and measures in their workshops, and one of the firm, Captain Sankey, gave evidence before the Select Committee of the House of Commons of 1895. He said that they were once fixing some engines in London, and that an exhaust-pipe had to be connected to a valve. "The width across the flange of the pipe was correctly shown on the drawing as 13 inches, but somehow or other the flange of the valve was marked with a tick after the 1 (1'3"), thus making it 1 foot 3 inches, and the mistake was not found out until the valve arrived in London." He added that "such a mistake could not have occurred if millimeters had been used. It would have been impossible. I believe that some manufacturers make a rule that all dimensions up to 24 inches are to be figured in inches, so as to get over this difficulty. But you only put it one step off; when you get beyond 24 inches you are as badly off as ever, because 2′ 2″ might be read as 22″, and so on." At the same time, Captain Sankey produced two drawings of an engine-cylinder, one drawn in millimeters, the other with British measurements, and he pointed out that in the latter the depth of the cylinder was given as $10\frac{3}{8}'' + \frac{1}{32}$, whereas in the former it was simply 241 millimeters. In one drawing the thickness was given as $\frac{5}{8}'' + \frac{1}{32}$, and in the other simply as 25 millimeters. He added, "In the one case you have to add them up to fractions, and bring them down to a common denominator; in the metric system, it is a simple addition sum in millimeters."

As to the necessity for many decimal places, if calculations have to be made with scientific accuracy, three or more places are often necessary, and as scientific men in all countries (including our own) have adopted metric weights and measures, we may assume that they would not have done so if they had not been satisfied as to the accuracy and the ease with which calculations could be made. Happily, this is a *fait accompli*, and needs no explanation; but in the ordinary affairs of life, in markets and shops, it would be ridiculous to reckon the weight of vegetables, sugar, tea, coffee, butter, etc., to the thousandth part of a kilo, or the hundredth of a pound. It would be equally ridiculous to reckon the length of cloth, ribbon, carpet, etc., to the thousandth part of a meter. In practice, vegetables, etc., are sold by the kilo, the pound, the half-pound, or by so many grams; and ribbon, etc., is sold by the meter, half-meter, or by so many centimeters.

It is the common practice of engineers in this country to use various empirical rules and constants, to shorten their calculations; but these are seldom wanted in the metric system, and as Sir Benjamin Baker pointed out to the Select Committee of the House of Commons, the metric system is so simple and direct that it needs no short cuts, and he considered that the need of these with Imperial weights and measures was an evidence of the inconvenience of the present system. As the chairman of the committee (Sir Henry Roscoe) remarked, "You do not want a short cut when you have a straight road."

To add together our present weights we must add up the ounces and divide by 16; add up the pounds and divide by 28; add up the quarters and divide by 4; add up the cwts. and divide by 20. In some cases, we can simplify these processes by short cuts; but taken at its best, it is a complicated and time-wasting arrangement compared with the simple addition of kilos and grams, and similar complications occur with subtraction, multiplication and division. A further great disadvantage of our present arbitrary weights and measures is that they have little or no relation to one another; whereas in the metric system there is one fundamental unit for all measures of length, capacity and weight. For large quantities the meter is the unit of length, the cube of this is a cubic meter, and the weight of a cubic meter of water (at its greatest density) is one ton. If we multiply this by the specific gravity of any substance, such as iron, coal, stone, etc., we know at once its weight per cubic meter. Or if we know the weight we can easily tell the cubic capacity. For smaller quantities we take the tenth of a meter, a decimeter or liter, and if this be cubed and filled with water it weighs one kilogram. If we multiply this by the specific gravity of any substance, we know at once its weight per liter or per cubic decimeter.

As a practical example let us suppose that we have a tank 2·3 meters long by 2 meters wide by 1·75 meters deep, and that we want to know how much water it will hold, and what the weight of the water will be. These are all the figures required:—

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1·75
 4·6
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1050
700
----
8·050
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The answer is—8 cubic meters and 50 cubic decimeters weighing 8,050 kilos, or 8 tons and 50 kilos.

In these simple relations of length, capacity and weight, the mind follows a rational sequence, and is assisted in passing from one stage to another, and it is chiefly this important principle which has recommended the metric system to so many scientific and practical minds. It happens that it is worked on a decimal system of notation, just as the counting by tens, which has been adopted in all countries from time immemorial; but the simplicity of the correspondence between the length, capacity and weight of the metric weights and measures does not depend on any particular system of notation. We have nothing like it in our Imperial weights and measures, they are all higgledy-piggledy, a motley crowd of survivals from various countries, having little or no connexion with one another, and incapable of being brought into line.

It is quite true that what is now known as the metric system was first adopted in France; but it is not a little interesting to Englishmen, especially to engineers, to know that it has been proved beyond doubt that it was our great countryman, James Watt, who started the idea of having a uniform system of decimal weights and measures for all countries. As unit of length he proposed the foot, while the unit of weight was to be the cubic unit filled with water, all being divided decimally from 1 to 10,000; he also proposed to weigh instead of measure liquids, and to weigh gases by the unit of water. This proposal was discussed by British and French savants, and in 1790 was adopted by the French National Assembly, while it was declined in England. It was afterwards confirmed by the French Academy of Sciences, and finally introduced in 1800, with the only alteration that instead of the seconds-pendulum, which is dependent on the geographical position, the meter was substituted as the unit of length. We see, then, that with admirable insight our countryman devised a simple decimal system of weights and measures, by which some of our old units would have been preserved; but yielding to our aversion to change, we let the opportunity slip. On the other hand, the French were quick to see the importance of Watt's proposal, and practically adopted the system he suggested, but introduced a larger unit of length, and in this they did not improve on his suggestions.

It is sometimes urged erroneously that the metric weights and measures are inaccurate and not suited for practical work, and the plain answer to an assertion of this kind is that they have been adopted throughout the world, not only for all scientific work, but for electric engineering also, and no one dreams of giving them up.

The writer had now mentioned several points in favour of the general adoption of the metric weights and measures, but he had by no means exhausted all that could be said, and he had not even referred to the simplifying of arithmetic, the saving of time in schools, and the other educational advantages which would follow their adoption. There was not time for him to discuss this aspect of the question, although it was of the greatest importance. He would pass on to the consideration of the urgent need for the adoption of the metric weights and measures for the sake of our foreign trade, and in the first place he would dispose of a rather prevalent idea that, after all, our foreign trade was not of sufficient importance to warrant putting ourselves to much trouble or expense about it. When Sir R. Giffen, who was head of the Statistical Department of the Board of Trade, gave evidence before the Select Committee of the

House of Commons of 1895, he spoke of the extent of our foreign trade, and estimated it at £1,000,000,000 for the year 1894. Of this, £768,000,000 were for direct imports and exports, and he estimated that "two-thirds to three-fourths is business done with foreign countries, in most of which the decimal system, if not the metric system of money, weights and measures prevailed." He added, "I am quite aware of the pretty extensive feeling amongst people who send goods to foreign countries, that they suffer inconvenience from not having the same measurements as in this country . . . The want of the metric system involves a serious injury to our foreign trade; it is an inconvenience which many manufacturers and merchants have expressed to me." He was strongly of opinion that the foreign trade of the country was not small, compared with the home trade; and when asked if the adoption of the metric system would facilitate the work in his Department, he said, "It would result in a great increase of intelligence, and the facility of understanding things on the part of those who study these questions." It is difficult to realize such enormous figures as those given by the Board of Trade statistician, but we cannot fail to be impressed with the vast extent of the interests involved, and in the face of such a statement from the highest authority in the country, no one can surely treat the subject as of second rate importance.

Mr. H. E. Woolmer, who for 25 years was connected with Sir Jacob Behrens & Sons, exporters of textile goods and machinery, etc., also gave important evidence before the Select Committee. He said that the tendency of all trade is to come nearer the consumer, to avoid the middleman. Formerly all business was with import houses in foreign countries, who bought by British weights and measures, and made a profit on converting them into local weights and measures for the retail buyers. Now, these middlemen are left on one side, chiefly on account of competition with foreign exporters, who go direct to the foreign retailers. British exporters now have to go to the foreign retailers also; but the latter do not understand our yards, pounds and ounces, and prefer to buy in meters and kilos. Not only have invoices to be made out on the metric system, for all Southern and Central American countries, as well as for nearly every European country, but in some places Customs declarations have to be made also, and "if we make the slightest slip of the pen we are fined, and heavily fined, even in cases where we declare more weight than the invoices should contain." He added that, "this involves very serious risk and great expense. Every shipping house in Manchester of any size has several clerks who do nothing but calculate and re-calculate from yards into meters, and from pounds into kilos, and so on." Needless to say, he considered that British traders, in those countries which have adopted the metric weights and measures, are at a great disadvantage compared with exporters from other countries where the metric system is used, and he remarked that our competitors make the most of the advantage.

Sir Benjamin Baker told the Committee that he was as familiar with the metric as with the Imperial weights and measures, and considered the former incomparably more simple. He thought that in many merchants' offices 20 to 30 per cent. of the clerks' time would be saved if the metric weights and measures were always used. As regards the use of decimals he said: "Of course I do not exclude halves and quarters, no one does; you use them if they are convenient, but for most mental work I begin by putting the thing mentally into decimals." He added that, "I have heard complaints over and over again from clients abroad. They say it is so inconvenient to have manufacturers' catalogues with dimensions in feet and inches, whilst the Germans and French have catalogues with the metric measures, which they understand. If they are ordering a centrifugal pump they do not bother to know whether a 12 inches or a 16 inches is what they want; they prefer to get it from catalogues where it is all in metric measures. And, of course, a double system would be very inconvenient in such cases, because of the duplication of patterns."

The Appendix contains a list of the countries which have adopted the metric weight and measures, and it will be seen that they represent a total population of over 448 millions.

From time to time, many of our Consuls abroad have urged the importance of our making and selling on the basis of the metric system. In October last, the Commercial, Labour and Statistical Department of the Board of Trade issued a valuable collection of *Opinions of H.M. Diplomatic and Consular Officers on British Trade Methods.* Extracts are given from 171 reports received from different parts of the world, since January 1896, and in a memorandum it is stated that "there is a general opinion among the Consuls to the effect that it is necessary for British traders to adapt themselves more to the requirements of their customers." Some of the causes are indicated which tend to place British trade at a disadvantage, and among these is the disinclination of British traders "to adopt the metric system in calculations of weight, cost," etc.

One of the reports (Amsterdam) says: "So long as Great Britain adheres to her present system of weights and measures, her manufacturers will always be greatly handicapped with the Continent." A year later, the same writer says: "I can but again and again point out the rapidly increasing necessity of adopting the metric system."

Another (Rome) remarks: "It is not a question of preference for one system of weights or measures, as compared with another; it is purely a matter of offering facilities to the buyer, who rarely understands the English system."

Following in the same line, another (Rustchuk) remarks: "The metric system is not perfect, but it exists and has been adopted by all the world except ourselves. We must bow to the inevitable."

In the *Board of Trade Journal** the following intimation is given:—"The Board of Trade have received information that a large amount of ironwork for bridges in Norway has been ordered from Antwerp. The contractors state that they would gladly have placed the order in England, but have lately gone over to order all their iron from the Continent, because they cannot get English makers to supply the work according to the metric system, and it is too complicated for them to work it all out into English measurements, feet and inches."

From Buenos Ayres comes the following:—"The want in Great Britain of the use of the metric system, which is the basis of the great bulk of first-hand business here, is undoubtedly a great drawback to British trade, especially in estimates for engineering work and such like."

From Kiel: "The inconvenience which was felt when the change was made in this country was soon overcome, and the reform met with universal appreciation."

Although the Germans were the last, or almost the last, to adopt the metric weights and measures, they have realized fully the advantages of them, and have been shrewd enough to make considerable capital out of them at our expense. For instance, the iron-and-steel manufacturers throughout the German Empire have adopted a standard classification of weights and sizes based on the metric system. Under this arrangement all angle-iron and bar-iron, of which the production in Germany is very large, is rolled by all the German manufacturers to identical metric weights and dimensions, and this system has not only been approved of, but has been followed and adopted in several other countries. We have, therefore, to face the fact that the German classification has been largely adopted, more and more to the detriment of the British manufacturer, who cannot adopt the metric system without upsetting the rolls and machines which he is obliged to keep going for his home trade. We have just seen what this has led to in Norway, while the British Consul in Amsterdam has reported as follows :—" In Holland there is an undoubted preference for the German sizes, based on the metric system, and it is chiefly owing to this that Germany has obtained many orders for railway bridges and other material." He adds : "As regards pipes for water-works, it is absolutely certain that the Dutch market is now lost to Great Britain, so far as new works are concerned, from the same cause." These are not the writer's words, but those of a responsible official on the spot: and as a matter of fact, it is known that not many months ago a Belgian firm obtained a large contract for water-pipes to be used in Holland, as they were willing to guarantee that the German classification should be followed, whereas our manufacturers were not prepared to adopt it.

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* 1898, vol. xxv., page 628.

The Select Committee of the House of Commons of 1895 reported strongly in favour of the metric weights and measures being adopted compulsorily after a lapse of 2 years, and when a joint deputation of the Associated Chambers of Commerce and the Decimal Association waited on the First Lord of the Treasury (Mr. Balfour) on the subject, he said :—" Upon the merits of the case I think there can be no doubt whatever that the judgment of the whole civilized world, not excluding countries which still adhere to the antiquated system under which we suffer, has long decided that the metric system is the only rational system." He added that :—" What men of science have long been obliged to do—not merely because the international character of science makes it desirable, but also because the calculations are so much more rapid, so much more convenient—what men of science for these reasons are obliged to do, I believe the commercial firms in all parts of the country are beginning to think they must do also. On that point I do not think that argument is possible."

The writer might also mention that in June, 1896, an influential Committee of Manufacturers and Inspectors of Weights and Measures, under the presidency of the Right Hon. Jesse Collings, M.P., reported in favour of the metric system last year, and said that :—" The adoption of the metric system would abolish the various and perplexing tables of weights and measures; would remove many anomalies which now exist; and would supply one order of weight and measure for all purposes."

Again, when a large and important deputation waited on the President of the Board of Trade (Mr. Ritchie) in March, 1899, he said that:—"I do not doubt that if the change asked for were supported by a great volume of public opinion, and if it could be adopted and brought into practice, it would be an advantageous one. Certainly for our export trade it would be an immense advantage, and I hope that our merchants and manufacturers, now that they are so alive to the disadvantages which accrue to them from the non-adoption of this system, may endeavour to do something in the way of adopting it."

Altogether the case seems to be overwhelming and to call for immediate action, but all the Government have done is to give us a permissive Act. This will never lead to a general change, but until a general change is made, those who manufacture, those who sell, and those who buy for the home trade will continue to use the existing weights and measures; and if engineers and manufacturers have to adopt the metric system for trade in metric countries, it follows that there must be two systems in use, one for the home trade, the other for the foreign. Let us see for a moment what this involves. It means a dual system of weights and measures in manufacturing, book-keeping, invoicing, making out price-lists, quotations, etc. It means that many machines or parts of machines, engines, etc., must be made to two sets of dimensions and weights. There must be two sets of gauges, and in many cases two set of patterns. Apart from this, there is the greater risk of mistakes, and with all these extra troubles and expenses it is impossible for the British engineer and manufacturer to compete on even terms with his foreign competitors, who work on the metric system and no other.

It is probable that the necessary alterations to patterns, gauges, etc., will put engineers to greater expense and inconvenience than other manufacturers; but, on the other hand, they stand to benefit more than others, especially in the export trade. It will also be well to remember that although the cost of the alterations required will be great in the aggregate, to the individual it will probably not be so serious as is sometimes supposed. New patterns will not always be necessary, and castings which have to be tooled are not made to the finished dimensions, so that in many cases they can be worked up to dimensions in millimeters. Again, as dimensions in millimeters will often be found to approximate to sizes in fractions of an inch, when new patterns are made they can be made to suit the metric basis. As to gauges and templates, they will in most cases have to be altered; but existing ones will not be lost, as plug-gauges can be reduced, while ring-gauges can be increased in diameter.

The greatest difficulty will doubtless be with regard to screw-threads, but even with these we should remember that in all probability the metric thread will be definitely adopted in France and other metric countries, and if we do not work to the metric thread also, we shall play into the hands of German and Belgian competitors, just as we have done already in the case of angle-iron and bar-iron. In the United States they have the Sellers thread, and formerly makers there advocated its use as a means of protection; but the opinion is growing steadily in favour of a metric thread, and there is little doubt that it will be adopted if the metric weights and measures are made compulsory. Some makers in the United States have already adopted it, so as to compete in metric countries, and since the conquest of Cuba and other islands there is a still greater inducement to do so.

In conclusion, he would point out what to some opponents may seem somewhat paradoxical, namely, that one of the great advantages which engineers have in working to millimeters is that, for ordinary purposes, decimal and vulgar fractions are avoided altogether in the workshop. If several dimensions in millimeters have to be added together, they are treated as whole numbers by simple addition. On the other hand, to add together quarters, eighths and sixteenths, and sometimes thirty-seconds, the workman often has to ask assistance, and not infrequently tries to settle the knotty point by marking off on a staff or board the various dimensions to be added together, and then measuring off the total. A really ingenious contrivance for wasting time and doing work inaccurately.

The writer could have said much more, but there was not time, and he would only remind members that the Government have admitted that the proposed change would be beneficial, but until they feel the pressure of public opinion they will not take the necessary steps to make the metric weights and measures compulsory. They also fear opposition from the engineering trades, and the writer ventures to hope that when our engineers and manufacturers have carefully sifted all the pros and cons, they will see that it is to their interest to adopt the metric system, and that they will bring their influence to bear on the Board of Trade, to give effect to the change promptly and thoroughly.

APPENDIX.

COUNTRIES WHICH HAVE ADOPTED THE METRIC WEIGHTS AND MEASURES.

Country.	Population.
Austro-Hungarian Territories	41,358,886
Belgium	6,262,272
Bulgaria	3,309,816
Finland (Grand Duchy of)	2,460,000
France	38,343,192
French Colonies and protected Countries	43,741,544
Germany	49,428,470
Greece	2,187,208
Holland	4,732,911
Java, etc.	32,617,000
Italy	30,724,897
Italian Dependencies ..	6,258,800
Norway and Sweden ...	6,825,067
Ottoman Empire ...	39,212,131
Portugal, Azores and Madeira	4,708,178
Portuguese Dependencies	5,371,200
Roumania	5,800,000
Servia	2,256,084
Spain	17,565,632
Colonial Possessions ...	9,695,567
Switzerland	2,986,848
Japan	41,089,940
Mauritius and Dependencies	371,655
Argentine Republic ...	4,257,000
Bolivia	2,019,549
Brazil (Republic) ...	14,002,335
Central America... ...	3,053,000
Chili	2,915,332
Colombia (Republic) ...	3,878,600
Ecuador	1,271,861
Haiti	960,000
Mexico	12,056,046
Peru	2,621,844
San Domingo (Republic)	610,000
Uruguay	728,447
Venezuela	2,323,527
Total	448,004,839

The **President** (Mr. J. A. Longden) said that Messrs. Willans & Robinson were makers of special machinery, and therefore they were in a good position for adopting the metric system of measures, because they simply had to make parts for their own particular engine, and had not got a trade for the supply of different parts of machinery, which had to replace, from time to time, parts already at work. He was glad to notice that the author dealt with the question of patterns, which was an important one, and he thought that the members were not prepared to throw their old patterns on one side either to please the French or any other nation. Mr. Dowson referred to the supply of water-pipes for Dutch towns, but instead of this trade being lost, foreigners were anxious to buy British-made pipes. Quite recently his own firm had been compelled to decline to tender, as it was not a mere question of measurement, but the buyers insisted upon the pipes being tested both at the works and after they had gone over sea. The contractor was also responsible for breakages in transit, etc. Every engineer who had foreign customers must be prepared to adopt the metric system in dealing with them, but this was a small matter compared with their home trade.

Mr. **Bennett** H. **Brough** (London) thought it was a matter of regret that the author had neglected the subject of mining in dealing with metric measurements. He had made out a good case from the point of view of the manufacturing engineer, but he gave no information as to how the proposed adoption of the metric measures would affect the mining industry. The mine-surveyor had already adopted the decimal system in his chain divided into 100 links, and further, 10 square chains made an acre: these were as convenient decimal measures as could be imagined. The conditions of the tenure of land were such that it was hardly likely that the acre would be replaced by the hectare as an unit of area in this country. The mine-surveyor when levelling used a decimal measure, in which the foot was divided into tenths upon the ordinary staff; and from practical experience of levelling on the Continent, he considered that it was much more convenient to read the staff when graduated in feet and tenths than in metres and decimetres. In linear surveying, the yard certainly presented advantages over the metre inasmuch as it more nearly approximated to the length of a human stride, which was a point of some importance in preliminary surveys. He could not help thinking that a radical change such as the author suggested would be difficult to make, and he thought that the Government had adopted the right policy in moving slowly and making metric measures merely permissible. Mr. Dowson, in an Appendix to his paper, gave the names of the countries and the populations adopting metric measures, but to make that table conclusive, he (Mr. Brough) thought that there should have been added a table exhibiting the population of the United Kingdom, the British Colonies, the United States of America, and Russia. It appeared to him that the numbers of population would be an argument against the extension of the metric measures rather than in favour of it. The alleged loss of markets, owing to British, American, and Russian manufacturers not using metric measures, was not one that concerned this Institution, which dealt with technical rather than commercial affairs; and manufacturers were well able to look after themselves, notwithstanding the pessimistic statements of British consuls.

Mr. C. C. **Leach** (Seghill) said that one difficulty in the proposed change of measures would be in the case of repairs to machinery, requiring pistons, bolts, nuts, etc., to replace old ones.

Mr. G. E. **Coke** (Nottingham) said that manufacturers exporting to foreign countries should translate their descriptive catalogues into the language of that country, and there was nothing to prevent them from adopting the measures in use in that country.

Mr. G. A. **Lewis** (Derby) said that the members were concerned with dimensions and weights of different kinds, and anything which could be adopted to simplify calculations should be adopted and supported by them as an Institution. He found that the decimal system assisted mathematical calculations in a marvellous manner, and it would save him material labour if the decimal system could be applied in all calculations in which he was interested. The table in the Appendix, attached to Mr. Dowson's paper, showed that metric weights and measures should be adopted in connexion with foreign trade.

Mr. T. E. **Forster** (Newcastle-upon-Tyne) said that the adoption of the metric system might be desirable, but the difficulty was in changing from one system to the other; and an Act of Parliament, if passed, could not over-ride the old system for many years. Engines were made on the present system, and it would be almost impossible to make a sudden change. Many people had a prejudice against the metric system, but it could be learned easily, as was evidenced in the erection of coke-ovens for the extraction of by-products, the plans being drawn to metric measures: but the enginewright became thoroughly acquainted with the use of a metric rule before he had finished the ovens.

Prof. H. **Louis** (Newcastle-upon-Tyne) said that Mr. Dowson had made a good case—if they were a brand new nation starting a new business—but they were an old-established, and perhaps a rather obstinate nation. The Cornish miner had a cwt. of 115 lbs. and a ton of 21 cwts., and he would prefer that the local custom of his trade should not be altered; the weight of pig-iron was different from that of every other material; but with all their different tons and hundredweights they managed to rub along fairly satisfactorily. No doubt the metric system was an advantage, in so far as it was a decimal system; but everybody could use a decimal system for the purpose of calculations, without adopting the metric system of weights and measures. It was better to have a number of different units to express what they wanted to say—in feet and decimals of feet—or to take a grain as an unit and work upwards by hundreds and thousands—or to work by hundredths and tenths of a ton.

Mr. G. J. **Binns** (Duffield) said that the question of a yard stride was a rough-and-ready reason for objecting to a system which would relieve them from a great amount of trouble, and our children from many years of useless labour. He did not know what its effect might be on the fate of a nation, but if they could relieve those who were to come after them from these great chances of error, they ought to do it. Posterity had not done much for us, but the adoption of the metric system would perhaps bring us into line with other nations, whose plans and specifications were difficult to understand if we were not familiar with their system.

Mr. R. HOLIDAY (Featherstone) said that a large amount of time was wasted in learning the various British weights and measures. It seemed to him inconceivable that railway and other transport companies were spending enormous sums and great effort in shortening journeys by 2 or 3 minutes—as it seemed to be recognized that to save 1 or 2 minutes daily was of great importance—and yet we clung to old systems of weights and measures, which were the means of great waste of time.

The Rev. G. M. CAPELL (Passenham) said that he had had experience of the metric system on the Continent, and also of transposing British weights and measures into metric measures. He was satisfied that the metric system afforded enormous facility for rapid working of calculations, and further the men engaged in workshops abroad had a facility which was not to be found among our own English workmen, in consequence of their knowledge of the metric system. The calculations with regard to mine-ventilation, with which he was most familiar, were simply child's-play in the metric system, compared with the calculations which had to be made with British measures. He had been a manager of voluntary schools for many years, and it had always been a painful thing for him to see the amount of trouble required to drive our system of weights and measures into the minds of children, with the result that at 14 or 15 years of age they came out of school with but a very slight knowledge of the matter. For the good of future generations it would be of advantage to allow children to learn the metric system, which could be mastered with so much less trouble than our own. Further, the boys could obtain a little knowledge of algebra during the extra school-time at their disposal. He was glad to see that the Education Department were authorizing schools throughout the country to teach the metric system. Great Britain had the lion's share of the world's trade, and if the metric system was any help in doing that trade, it should be the aim of all looking forward to the future of the country to facilitate the advance of that system so as to bring us in line with other nations.

Captain H. RIALL SANKEY (Rugby) wrote that he fully endorsed Mr. Dowson's statements, and he hoped that the paper, and the accompanying discussion, would be another step forward towards the introduction of the metric system in this country.

Mr. M. **Walton Brown** (Newcastle-upon-Tyne) wrote that Mr. Dowson seemed to have overlooked the fact that objections could be raised to the use of any system of weights and measures. The need of uniformity of weights and measures in France had been discussed for many years, as different and peculiar systems were in force in many of the provinces. Thus the standard aune or ell at Paris contained 3 Paris pieds (each of 12 pouces) 7 pouces 10$\frac{5}{6}$ lignes (12 lignes to the pouce); at Troyes, it measured 2 pieds 5 pouces 3·7 lignes; in Britanny, 4 pieds 3 pouces 1$\frac{3}{4}$ lignes; in Bordeaux, 3 pieds 8 pouces; Valenciennes, 2 pieds and 4 lignes; etc. In Foix, the standard measure was the canne, of 5 Paris pieds 4 pouces and 9$\frac{3}{8}$ lignes; in Avignon, it measured 6 Paris pieds 1 pouce and 3 $\frac{1}{16}$ lignes; etc. These varying ells were subdivided (1) into thirds, sixths and twelfths, and (2) into quarters, halves, eighths and sixteenths. The difficulty of expressing these subdivisions in pouces (inches) and lignes (twelfths) will be readily recognized, and they indicate the variations of the numerous linear measures in use in France prior to the adoption of the metric system. The measures of volume and area were similarly numerous and more variable, different standards being used in the different provinces for different substances. Different standards of weight divided in different ways were in use in most of the provinces of France. Under such circumstances the metric system was adopted in France, and probably for similar reasons in other countries. It would be interesting if Mr. Dowson would indicate the countries where metric weights and measures are solely in use, and those in which they are jointly used with some other system. The Emperor Napoleon, after stating his objections to the metric system, said that "the new system of weights and measures would be a source of trouble and difficulty for many generations, and it was probable that the first commission charged with the verification of the measurement of the meridian would find that a correction was required.[*]"

There are many things against the adoption of an universal decimal system. Thus, there are four seasons and about 12 lunations in a year, and no one has proposed that a day should consist of 10 hours, or a week of 10 days, or a year of 10 months. There are four cardinal points, but no one has proposed that there should be 10 divisions of the perimeter of a circle in lieu of 4 quadrants. All over the world, notwithstanding the metric system, both measures and moneys are divided familiarly into halves, thirds, quarters, sixths, eighths, twelfths, and sixteenths. And there is no doubt that, as a whole, the British system of weights and measures satisfies our needs and complies with our usages.

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[*] *Mémoires pour servir à l'Histoire de France sous Napoléon*, by Comte de Montholon, vol. iv., pages 213 to 218.

The metric system was nominally established in France in 1795, and made compulsory in 1839, yet some of the former measures are still in use—tool-steel and wood for buildings are measured in pieds, pouces and lignes; beer in canettes or pots; milk in pintes; wine in barriques, feuillettes, demi-setiers and chopines; fire-wood in cordes; gravel in toises; charcoal, grain, etc., in boisseaux; etc. And it should not be urged that British measures should be abolished, because it happens that a bushel of various kinds of grain has as many different weights, and even metric measures would equally vary in the weight of the contained grain.

In many calculations, the metric system is as cumbrous as its British rival. Thus, in a boiler, 2·45 metres in diameter, the inside circumference will be 7·69 metres, and the plate being 13 millimetres thick, the circumference in the centre of the plate (diameter of 2·463 metres) of 7·73776 metres must be called 7·738 metres, and if there are 100 rivets they will be spaced 77·38 millimetres apart. It is just as easy to make a similar calculation for a boiler 8 feet $\frac{7}{16}$ inch in diameter, made of $\frac{1}{2}$ inch plates. A workman can as easily measure a length of 12$\frac{61}{64}$ inches (even if he follows the rule along on the antique plan of $\frac{1}{2}$ inch, $\frac{1}{4}$ inch, $\frac{1}{8}$ inch, $\frac{1}{16}$ inch and $\frac{1}{64}$ inch*) as 0·329 metre (following the metric rule, say 3 decimetres, 2 centimetres, 5 millimetres and 4 millimetres more).

The change from pounds per square inch of pressure to kilogrammes per square centimetre would be abrupt, as 1 kilogramme per square centimetre is equivalent to 14·2 pounds per square inch. Section-paper, ruled 10 or 12 lines to 1 inch is more convenient for use than squares of 1, 2, 3, 4 or 5 millimetres.

All concerned in the mining industry would suffer severely from the change (except in the case of newly-opened mines). Special artificial scales would be required for all plans attached to leases, and for all plans of the workings and of the Ordnance Survey; and the slightest error might lead to costly law-suits, even if it did not result in serious loss of life. Miners' wages are dependent upon the ton, inches of height, inch of thickness per linear yard of defined widths, etc., and the conversion into metric measures would lead to endless disputes. Take the case in which miners are now paid ½d. per inch for removing stone in a working-place driven 4 feet wide; the metric equivalent would be ½d. per 12·69 millimetres thick and the place would be driven 1·219 metres wide—the miner would probably insist on the ½d. being paid for each unit of 12 millimetres of thickness and 1·2 metre wide, equivalent to an advance of wages of 7 per cent. In another case, the miner may be paid 9d. per square yard for holing in the coal, and he would certainly insist on 11d. instead of 10·765d. per square metre.

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* *Trans. Inst. M.E.*, 1899, vol. xvii., page 328.

Ignorant prejudice is always alleged as the sole basis of the opposition to the metric system, but is there any scientific reason for the adoption of a Centigrade thermometric scale? No scientific plea can be urged for a scale, which measures upwards from the freezing-point of water, and it is not necessary to have 100 degrees between the freezing and boiling-points. The Centigrade degree is too large, and endless confusion results from the use of the (—) sign, which is frequently accidentally omitted; and if anyone desires to try his capacity and temper, let him calculate the average temperature of a month, in which half of the recorded temperatures are below 0° Cent.

He (Mr. Walton Brown) was able to make calculations in metric measures, but he strongly deprecated their adoption in Great Britain, (1) as they do not facilitate mental calculations, (2) owing to the risk of a decimal point being misplaced, (3) the confusion of units,* (4) it requires the use of more figures than the present system in ordinary calculations, and (5) the use of a comma in lieu of the decimal point, in order to prevent mistakes in interpreting dimensions sent from metre-using countries.

Mineral products, when exported, are usually sold by the ton, and it would be as easy to transform the weight from the British to the metric ton, as it is for the foreign merchant to pack 8 ounces of sardines or 300 yards of thread for sale in Great Britain. British consuls generally condemn British weights and measures—but they do so for convenience of transcribing statistics in their periodic reports—and not as producers who supply the markets of the world. A consul in Spain states that Germans are absorbing trade because they sell their metric goods for pesetas (they take a great risk, as exchange varies from 20 to 50 pesetas for a sovereign). On the contrary, iron-ore is sold in Spain for shillings and pence per ton for export to this country.

The nomenclature of the metric system and the use of the same prefix in the various systems of measures facilitates error and prevents the use of abbreviations. The unit measures—the metre, are, stere, litre and gramme—differ in their basis of dimensions, and consequently a square metre is not an are, and a cubic metre neither a litre nor a gramme. In order of dimensions, the units are : a millilitre (usually called a cubic centimetre) is a gramme, a litre is a cubic decimetre, a stere is usually called a cubic metre, an are is a square decimetre, and a quintal and tonneau (or millier) are required to complete the series of weights. There is no uniform derivation of units, each unit being derived from another by multiplication or division before its square or cube is taken as a standard of weight or measures. And, owing to error, the theoretical relationship does not exist between the cubic decimetre, the litre and the volume of a kilogramme of water at a temperature of 4° Cent. and a pressure of 760 millimetres of mercury.

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* It is not unfrequent, on the same page, to find a dimension variously given in metres, decimetres, centimetres and millimetres.

Again, a month consists of four weeks, a circle of four quarters, or of six arcs upon a chord equal to the radius, and a balance, compass and square are used for division into halves.

With regard to the loss of British trade (if any) occasioned by the non-adoption of the metric system, it should not be forgotten that the bulk of our exports made to specific dimensions are sent to countries (Australia, Canada, China and the Far East, India, Russia, South Africa, West Indies, United States of America, etc.) where British measures are in use or generally recognized. This trade would be embarassed and thrown open to competition from metre-using countries, if British measures were abolished and metric measures were adopted. If manufacturers of goods exported to metre-using countries cannot alter their methods, without compulsory enactment, it is very unfair that the metric system should be enforced on manufacturers, who only export to countries where British measures are now in force.

Mr. J. E. DOWSON (London), replying to the discussion, said that one or two speakers had remarked that this was hardly a subject which concerned them as mining-engineers. Others had answered that point sufficiently by reminding the members that they were concerned in the measuring and weighing of various substances, and he took it that they could not isolate themselves from the world at large. Apart from educational and other important considerations, he hoped that they would bear in mind one very large question with which they were concerned, namely, their foreign trade, and although it had been said that they rubbed along very well, they had to recognize the fact that the conditions in which they lived were different from what they were years ago, when the British manufacturer could almost dictate his terms to foreign buyers.

Some speakers disagreed with the opinions of the Consuls he had quoted: but he put them forward as they were independent, and came from gentlemen who were better qualified to give an opinion than those at home, as they saw how the subject affected trade on the spot. If they looked over the large number of Consular reports received, they would see that they represented a fairly general opinion from various parts of the world, and taking a broad view of the matter, they could not but recognize the fact that they had to work against keen competition, and that among other things they had to contend with the facility which their competitors had in the matter of weights and measures. With regard to water-pipes, he might say at once that he did not give any opinion of his own, he quoted a report to the Board of Trade by the British Consul in Amsterdam, who said that the Dutch required the metric classification to be adhered to.

Mr. William Cochrane (Newcastle-upon-Tyne) said that was not his experience ; his firm had supplied large quantities of water-pipes to Holland, and their tenders had never been refused because they would not supply the pipes to metric measures.

Mr. Dowson, continuing, said as to the difficulty of changing from the one system to the other, it was easy to exaggerate it, but the experience of other countries showed that if the public were well prepared beforehand, as was done in Germany for instance, there was remarkably little trouble. When Messrs. Willans & Robinson adopted the use of metric weights and measures, they were naturally a little nervous as to how the men would take to them, but he was pleased to hear from Captain Sankey that there was extraordinarily little trouble; and in a few days they got quite familiar with them. In the drawing-office, as the members might suppose, there was practically no trouble: a few mistakes occurred, but nothing of serious consequence. As to the totals of populations of other countries that had not adopted the metric system, he could have given them, but this had not occurred to him as necessary. The figures were easily obtainable, but whether or not English speaking races were included, the fact remained that 448,000,000 had adopted the metric system, and a considerable number of these should be their customers. He thought he was right in saying that the United States and ourselves were running together in the matter: they had about the same feeling, some for and some against the metric weights and measures. If the United States decided to adopt the metric system compulsorily, Great Britain would doubtless follow at once; and if, on the other hand, Great Britain adopted them, that would largely influence the U.S.A. in doing the same. As regards Russia, which was the only other civilized country of importance which had not adopted the metric system, they had carefully considered it, and he had authority from a government official to say that if Great Britain adopted the metric system Russia would adopt it as a matter of course.

He purposely omitted to deal with the question of local weights and measures, which added to the trouble and confusion caused by the Imperial weights and measures. There was not time to deal with this, but he might add that the representative of the Board of Trade, told the Select Committee of the House of Commons, that if the metric system were adopted, it would very largely assist in abolishing the use of local weights and measures, which were a hindrance and trouble to traders.

As regards Mr. Walton Brown's written communication, he seemed to have overlooked the fact that the paper referred strictly to metric weights and measures, and not to other subjects: moreover he (Mr. Dowson) had started by saying that time compelled him to limit his remarks to some of the points which had a bearing on the work of engineers. The paper in no way referred to the seasons of the year, the number of hours in a day or week, or the number of months in a year; nor did it refer to the points of the compass or the Centigrade thermometer. None of these had anything to do with the metric weights and measures, and need not therefore be discussed.

As to what may have been the opinion of the first Napoleon, no one can question the military genius of the great soldier-emperor, and he may have been an authority in his time on the subject of weights and measures; but whether he was so or not, it can hardly be supposed that the manufacturers and traders of to-day, and the public of this country, will be much influenced by what Napoleon, or any one else, may have said on the subject some seventy or eighty years ago. Since then our commercial relations with other countries have changed greatly, the nations which have now adopted the metric weights and measures represent a population of over 448,000,000, and as Sir R. Giffen has told us a large proportion of our foreign trade is with these very countries.

The old French weights and measures enumerated by Mr. Brown may be interesting historically, but as they are not only obsolete but illegal, they do not seem to affect the question of whether or not we should adopt those of the metric system. As to some old names being still used, that is probably the case in all countries where the metric weights and measures are used: this is a point specially referred to in the early part of the paper, and need not be repeated. If Mr. Brown would refer to the evidence given before the Select Committee of 1895, he would find that in Austria, Germany, and other countries the necessary changes were effected in a short time and with much less friction than was expected.

As to decimals being used to the total exclusion of halves, thirds, fourths, etc., that is a misconception altogether, and is specially referred to in the beginning of the paper. No one has recommended it, nor is it desirable from any point of view. Nor would any one familiar with the metric system follow Mr. Brown in expressing 0·329 metre, as "3 decimetres, 2 centimetres, 5 millimetres, and 4 millimetres more." The plain man would say, "329 millimetres."

As to the British Consuls abroad, Mr. Brown certainly does them an injustice. He says, they "generally condemn British weights and measures—but they do so for convenience of transcribing statistics in their periodic reports—and not as producers who supply the markets of the world." These gentlemen are in responsible positions, with a thorough knowledge of all affecting our commerce in the localities in which they represent the home country, and when they are asked to report on questions affecting our commercial interests in those localities, the least we can do is to believe that the opinions they give are *bonâ-fide*, and not based on the small personal question of whether or not their calculations of statistics would be affected one way or the other. In several cases the Consuls' recommendations as to the metric weights and measures being adopted have been confirmed independently by the Board of Trade, and by Agents of the Foreign Office. Take for instance the case of Egypt. On November 17th, 1896, the Foreign Office in London wrote as follows:—"I am directed by the Marquis of Salisbury to inform you that a dispatch has been received from H.M. Agent and Consul-General in Cairo. Lord Cromer considers that a very general opinion undoubtedly exists in Egypt that British trade with that country would benefit by the adoption of the metric system of weights and measures." If space permitted other instances could be given, but this and the Board of Trade memorandum referred to in the paper should suffice to show that Mr. Brown's opinion of the consular reports is a wrong one.

The PRESIDENT (Mr. J. A. Longden) remarked that the population of the world was probably 1,500,000,000, so that there was about 1,000,000,000 who did not use the metric system, and there was not a single English speaking people included in the 450,000,000 who had adopted the metric system. He had pleasure in proposing a vote of thanks to Mr. Dowson for his paper.

The motion was seconded by Mr. W. COCHRANE, and cordially approved.

Mr. H. F. BULMAN read the following paper on "The Kalgoorlie Gold-mines, Western Australia":—

THE KALGOORLIE GOLD-MINES, WESTERN AUSTRALIA.

By HARRISON F. BULMAN.

Situation.—The half dozen or more valuable gold-mines which have brought Kalgoorlie into prominence during the last 5 years are all contained in a small area about 1½ miles in length and ¾ mile wide, situated 3 miles southward of Kalgoorlie, and connected with it by a light railway, with a frequent service of trains. From the masses of ironstone appearing at the surface of the low hills which cover this auriferous patch of country, it has received the name of the "Boulder."

Kalgoorlie is reached from Perth, the capital of Western Australia by a railway-journey of 378 miles occupying 19 hours. Coming from Perth the line ascends the Mount Darling range, a rise of 1,000 feet, on to a wide tableland on which stand Coolgardie, and 20 miles north-east of it lie Kalgoorlie and the adjacent mines. The elevation of Kalgoorlie is 1,240 feet above sea-level. This extensive tableland is covered with a natural vegetation of low scrub and small gum-trees, but in the neighbourhood of the mines all vegetation has been denuded, and the surface is an arid waste of reddish-coloured, gritty sand and gravel. Much of this sand carries free gold, and all over the Boulder district men may be seen digging up the sand and gravel, and riddling it over sieves to separate the particles of gold by the method known as dry-blowing (Fig. 1).

Rainfall.—The annual rainfall is not more than 6 inches, and any strong wind causes the disagreeable phenomenon of a dust-storm. These dust-storms and the want of water are the only serious objections to the climate.

Telluride Ores.—Special interest attaches to the discovery of telluride ores at the Boulder, owing to their comparative rarity, and also to the intimate association between tellurium and gold.

Tellurium is the only element with which beyond a doubt gold occurs chemically combined, and tellurides are usually accompanied by gold in a free state also. But it is a mistake to suppose that the presence of tellurium always denotes high-grade gold-ores, though it has been invariably accompanied hitherto by gold in some proportion.

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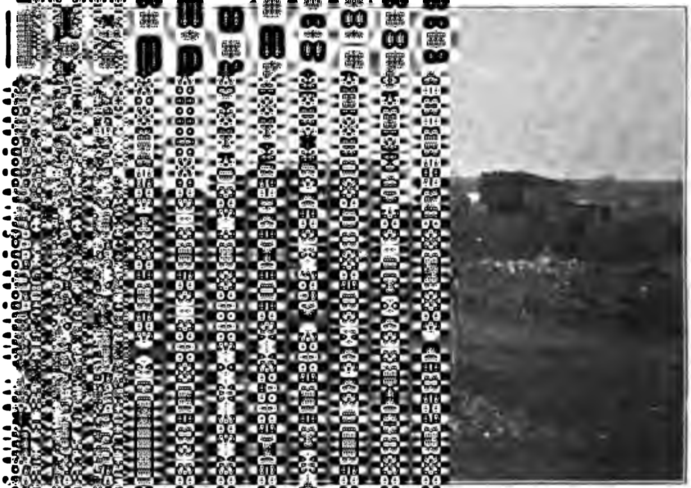

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Mr. George W. Card (the mineralogist to the Geological Survey of New South Wales) examined with the microscope 50 thin sections of rocks carefully prepared from specimens gathered by Mr. Pittman and by Mr. W. Frecheville from the ore-bodies as well as from the adjacent country-rocks in ten of the mines. Their investigations prove that the country-rock is the same throughout the field, and that the ore-bodies are simply more highly altered rock of the same character. Its principal original constituents, according to Mr. G. W. Card, are quartz, felspar, ilmenite, magnetite and apatite. The greenish colour of much of the rock is due to chlorite finely disseminated through it. Quartz and titaniferous iron-ore were detected in all the specimens.

The lode-stuff is the same as the country-rock, but has undergone more alteration. It exhibits a highly schistose structure. In the words of Mr. Card:—"The lodes represent belts along which the crushing effects have been most severe, and the deposition of secondary material more abundant. They are in fact more highly altered portions of the country-rock.* The tellurides of gold, together with the associated carbonates of lime and magnesia and the secondary quartz, have been introduced into the ore-body by solutions which found ready access along the planes of parting produced by the incipient foliation."† The presence of carbonates of lime and magnesia is important, as it renders the treatment of the ore by chlorination impracticable.

Telluride Minerals.—As pointed out by Mr. Pittman, the telluride-minerals seen in the Boulder mines are some of them of a yellowish colour and others an iron-black. Of the former, there have been recognized sylvanite or graphic tellurium, a telluride of gold and silver represented by the chemical symbol (Au Ag) Te_3, and having a specific gravity of 7·9 to 8·3; and calaverite, which has a specific gravity of 9·377, and has been chemically analysed as follows:—

Tellurium	56·64
Gold	41·76
Silver	0·80
	99·20

Of the dark-coloured minerals, the telluride of mercury, coloradoite, has been found, and a new mineral named by Mr. Pittman, "kalgoorlite," which is composed of the tellurides of gold, silver and mercury, with a trace of copper. It was analysed by Mr. C. H. Mingaye, analyst to the Department of Mines, New South Wales, as follows :—

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* *Records of the Geological Survey of New South Wales*, 1898, vol. vi., page 22; and *Annual Report of the Department of Mines and Agriculture*, 1897, page 193.

† *Records of the Geological Survey of New South Wales*, 1898, vol. vi., page 39.

Mercury	10·86
Gold	20·72
Silver	30·98
Copper	0·05
Sulphur	0·13
Tellurium (by difference)...	37·26
Specific gravity	8·791

Oxidized Zone.—The upper 100 to 200 feet next the surface have been oxidized by atmospheric influences. The sulphides and tellurides have been decomposed, and the gold exists in a free state. But there is no very regular horizontal line between the two, the sulphide-ore being sometimes found near the surface side by side with the oxidized. Free gold is found associated with the sulphides and tellurides at the lower levels to the extent of 10 to 30 per cent.

Character of Lodes.—The lodes are lenticular in shape, thickening and thinning both in a vertical and an horizontal direction. Clearly defined side walls are seldom seen. The limits of the productive ground have to be determined by assaying. Most of the country-rock carries gold in small quantities. At the Lake View South mine, cross-cuts have been driven in the country-rock for hundreds of feet at right angles to the lodes at different levels, and all this ground has been proved to carry 1 to 4 pennyweights of gold per ton. Sometimes well-defined vertical walls cut across the lodes at right angles to them without affecting the gold-bearing character of the ground at either side of the "parting." Irregular quartz-veins and veins of ironstone run for short distances sometimes parallel to the lodes and sometimes at right angles to them. Flat veins rich in gold occur abutting against the main ore-body. Not infrequently, the lodes divide into two arms, enclosing between them a mass of unproductive rock, termed locally "a horse of mullock." At the Great Boulder mine, one of these branches passes out of their take into the adjacent Golden Horse Shoe area, and returns again 100 feet farther on into the Great Boulder take.

As great a width as 64 feet of high-grade ore has been found. Just before the writer's visit in October, 1898, considerable interest had been excited by the finding in the 500 feet level at the Tetley shaft of the Associated Gold-mines of West Australia Company of a lode 40 feet in width carrying 3 to 4 ounces of gold per ton. This was the lowest level then explored at any of the Boulder mines.

The lodes are roughly vertical, the levels at increasing depths being as a rule nearly beneath each other, but often they incline from side to side at different depths. For instance, at the Kalgurli mine a lode, proved by their main shaft passing through it, to be sloping to the westward between the 200 feet and 300 feet levels, is seen at the 300 feet level to have altered its inclination to the eastward, and to be coming into the shaft again.

What general underlay exists is said to be in a west-south-westerly direction. An apparent underlay is sometimes due to horizontal slides, for instance, at the Ivanhoe mine three of these exist—all in the same direction—between the surface and the 300 feet level.

The lodes are pockety in character and sometimes pinch out altogether; thus, at the Lake View Consols mine this occurred recently at the 450 feet level, but the general geological conditions point to their continuance in depth. In the words of Mr. Pittman, "When the mode of occurrence of the tellurides is studied, when they are seen to be disseminated through dykes of igneous origin, there are, I think, reasonable grounds for expecting that the enrichment of the deposits by these minerals will continue, probably with intermissions, to very considerable depths." *

System of Ore-getting.—There is nothing novel or unusual about the system of getting the ore. Rectangular shafts are sunk vertically in the country-rock. Their dimensions run about 10 feet by 4 feet inside the timber lining. An ordinary contract price for labour, sinking and timbering, is £5 per foot. Two small cages, holding one truck each of a capacity of 7 to 10 cwts. of ore, run in wooden guides. The cages are always fitted with safety-catches to grip the guides in the case of a broken rope; these catches are said to be quite satisfactory. A third division of the shaft holds pumps.

Levels 7 feet high by 5 feet wide are driven in the lode at vertical intervals of 100 feet or sometimes less, and are connected by rises and winzes. The ground between is removed by overhand stoping, the ore falling through timbered chutes closed at the bottom by sliding-doors into the truck on the level below. The excavations are filled with stowing, which saves much timbering. The refuse sands from the cyanide-vats are used for this purpose, the only drawback being that this material seems to have a somewhat injurious effect on the health of those engaged in stowing it.

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* *Annual Report of the Department of Mines and Agriculture*, 1897, page 141.

Tunnelling.—Tunnelling and sinking proceed rapidly, the rocks not being particularly hard, considering that they are igneous. In one instance a cross-cut 7 feet by 5 feet at the 300 feet level had been driven a distance of 40 feet in a fortnight by 6 men, 2 per shift, using compressed-air drilling-machines, and doing their own trucking to the shaft, a distance of 500 feet. In hard sulphide-stone, 12 feet a week is a fair rate of progress with 6 men, following each other in pairs, and hand-drilling.

The employment of machine-drills enables more rapid progress to be achieved, but makes little difference in the cost per foot, according to the statement of several of the managers. The cost of driving the levels is from £1 15s. per foot in the softer ground of the upper oxidized zone to £2 10s. per foot in the harder strata below. This includes the cost of explosives and of repairs to drilling tools. To stimulate the men, it is customary to pay a bonus when they drive more than a certain number of feet per week. At one mine this is £1 a week to each man if he exceed 16 feet, and at another £2 a foot for each foot over 19 feet a week.

Timber.—Very little timbering is required in the levels. They are kept narrow until reached by the stopes from below, and are then stripped to the full width of the lode. A tree known as the salmon-gum grows plentifully in the district, and makes good mine-timber. It gets almost as hard as metal, so that holes cannot be bored in it by hand. It costs 2½d. to 5d. per running foot, according to size.

Fuel.—Salmon-gum wood is used for fuel under the boilers, costing for this purpose 18s. to 20s. per cord (128 cubic feet or 35 cwts.), or 10s. 6d. per ton. The high price of coal, which has to be brought from Newcastle in New South Wales, at present prohibits its use. The development of the West Collie coal-field, near Bunbury, Western Australia, may perhaps provide a cheaper fuel. Doubts were expressed in the autumn of 1898, as to whether the coal was of adequate quality, but it is hoped that it may improve at greater depths than have yet been explored. The supply of timber is necessarily becoming smaller and farther afield every year.

Wages.—Wages are high. Miners are paid 11s. 8d. for an 8 hours' shift, working dry, or £3 10s. per week, and for wet working 13s. 4d. a shift, or £4 per week. Truckers (putters) are paid 10s. for an 8 hours' shift, and mechanics and carpenters 14s.

The cost of living is considerable, though it is, now, much less than it was before the advent of the railway. Single men pay £1 to £1 10s. per week for board and lodging. The miners' dwelling-places are rough shanties in appearance, built of wood or of hessian canvas, stretched over a wooden framework, but in the hot, dry climate they answer their purpose quite as well perhaps as more substantial structures (Fig. 1).

Water.—Fresh water is an expensive item, costing 7s. 6d. to 8s. 6d. per 100 gallons. The mining companies allow their workmen 2 to 3 gallons a day gratis. The water being naturally saturated with salt, requires to be distilled and condensed, before it can be used for domestic purposes.

Most of the supply is pumped from the mines, and the cost of pumping and condensing is ½d. to 1d. per gallon. The condensing-plants at some of the mines have a capacity of 5,000 gallons a day. The following is an analysis of mine water made by Mr. Bowen Jenkins :—

	Per Cent.
Chlorides of magnesium and sodium	6·95
Carbonate of lime	0·86
Alumina and oxide of iron	0·49
Sulphur	0·12
Total solid matter	8·42

Water-supply.—Works are now in progress for bringing a daily supply of 5,000,000 gallons of fresh water from the Mount Darling range near the coast, a distance of 328 miles. At Mundaring, 26 miles from Perth, a weir is being constructed across the Helena gorge, which will hold back the river for some 7 miles, and form a reservoir capable of containing 4,500,000,000 gallons of water. The weir will be 720 feet long on the top and 110 feet high near the middle, and is being made of cement-concrete faced with ashlar-work of a very hard micaceous granite. The contract for 328 miles of steel pipes, 30 inches in diameter, was let in October, 1898, to Australian contractors. The water has to be raised a height of 1,313 feet to the Coolgardie plateau. There will be 8 pumping-stations with large reservoirs at each station. The greatest distance between adjoining stations will be less than 70 miles. The estimated cost is £2,300,000.

Surface-plant.—The surface-plant for raising the ore is much the same at all the Boulder mines.

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e, and supporting at their
lleys, and at a lower level

red horizontal engine is
at most Australian metal-
one drum, as used at coal-
worked independently of
the crank-shaft, side by
igh-pressure steam is used,
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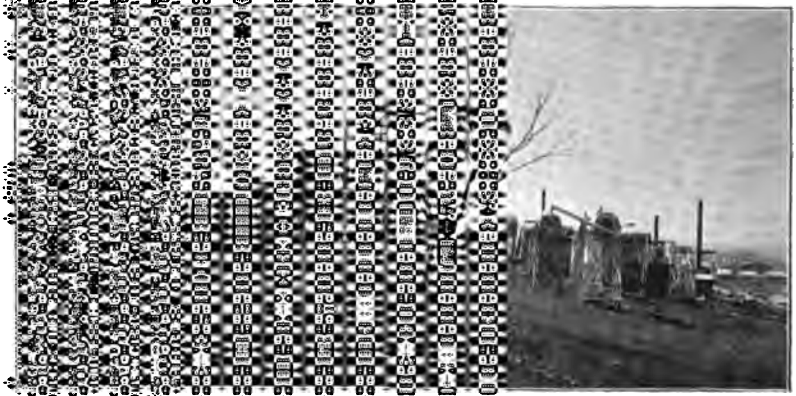

GOLD-MINES OF WESTERN
ONDENSING-PLANT ON THE

s, the air being used at a
for driving rock-drills, and
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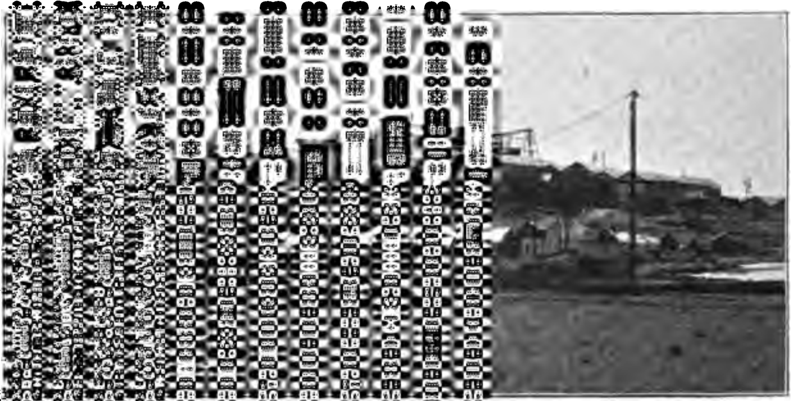
t some of the mines in con-

[illegible] upper levels is treated at [illegible] amation and cyanidation of [illegible] of the gold-content is thus [illegible] iew Consols (Fig. 3), where [illegible] pounds each, running at an [illegible] fall of 6 inches, driven by [illegible] pes. The ore, previously

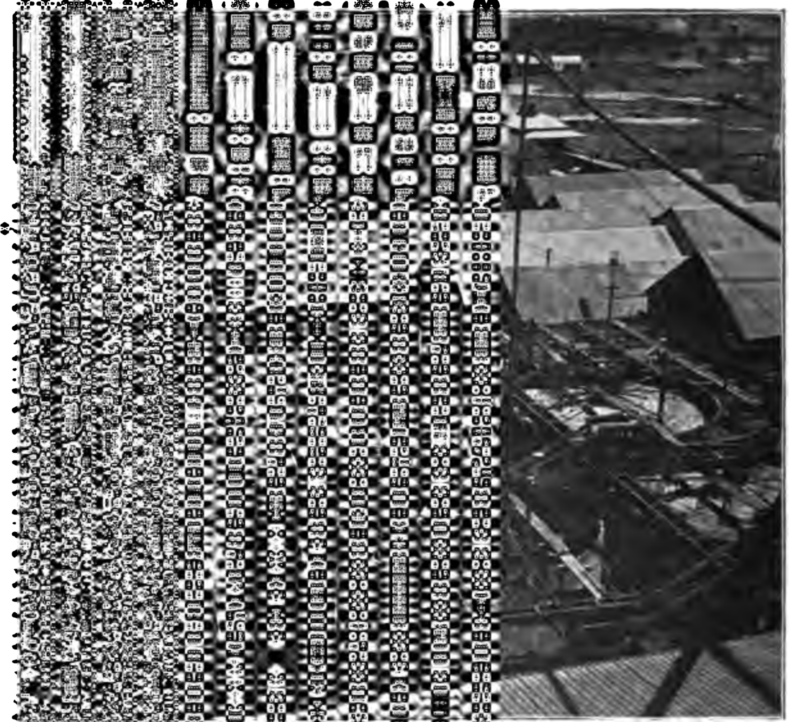


[illegible] VIEW CONSOLS MILL.

[illegible] into the mortar-boxes by [illegible] tons of ore daily, or 4 tons [illegible] mill in the autumn of 1898. [illegible] plates, and then over canvas [illegible] deposited in the form of

[illegible] wheel, and flow into settling- [illegible] (Fig. 4). These distributors [illegible] ating in an horizontal plane [illegible] am of tailings is introduced [illegible] ng at their ends, and causing [illegible] the outflow. The arms are [illegible] rt, so that the pulp is distri- [illegible] vier sands fall to the bottom, [illegible] through vertical openings at [illegible] ers as the level of the fluid [illegible] ted some 50 per cent. of fine [illegible] vats, are so detrimental to [illegible]

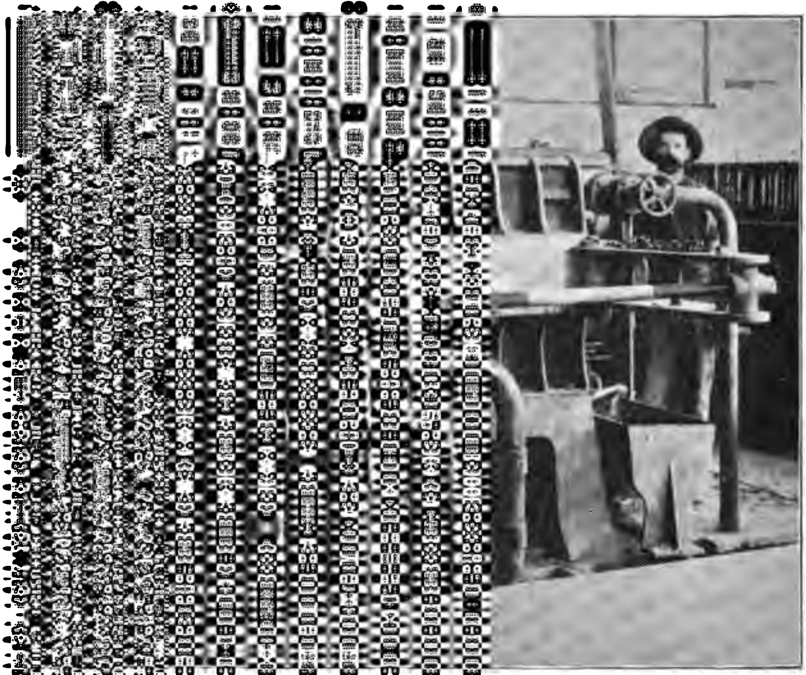
[illegible] aching-vats, in which they [illegible] f potassium cyanide slowly [illegible] gold, and the gold solution [illegible] filings.



[illegible] EW CONSOLS MILL; SHOWING [illegible] ING DISTRIBUTORS, TAILINGS- [illegible] ETC.

[illegible] pth of zinc-shavings in the [illegible] the solution is made to flow [illegible] utive compartments, down [illegible] action, which is not fully [illegible] form of a black, muddy [illegible] attention is required during [illegible] riods, usually every month, pure gold slime is washed off, bstances which absorb the of soda), and melted into

he Lake View Consols mine hter pulp overflows into two



Lake View Consols Mill.

uced at a pressure of 70 to 80 of these vessels, the slimes into filter-presses, standing in There are 10 Dehne filter- potassium cyanide is pumped presses, and then the wash- ut 4 hours. The resulting the gold is precipitated, as

Gold Yield and Cost.—This slime-treatment plant commenced operations at the beginning of April, 1898, and during the 5 months, ended August 31st, 1898, they treated 7,423 tons of slimes, obtaining 2,794·07 ounces of bullion, which is a yield of 7 dwts. 12·67 grs. per ton. The cost was 10s. 8·452d. per ton, a cost which Mr. Callahan, the general manager, expects to reduce.

By the potassium-cyanide treatment of the tailings 29,206·625 ounces of bullion were obtained during the year ended August 31st, 1898, from 36,182 tons of sands, a yield of 16 dwts. 3·50 grs. per ton, at an average cost of 6s. 7·6d. per ton.

During the same period 64,687·7 ounces were recovered in the battery by amalgamation from 57,725 tons of ore, a yield of 1 oz. 2 dwts. 9·6 grs. per ton, at a cost of 10s. 1·2d. per ton.

Adding some concentrates and sulphide ore which were shipped, and treated at smelters away from the mine, the total bullion produced by the Lake View Consols mine during the year ended August 31st, 1898, was 103,946·192 ounces, of a value of £414,368 5s. 7d. from 57,920 tons of ore treated.

According to figures, contained in Mr. Callahan's report, issued to the shareholders, the average value of the ore was £7 3s. per ton. The total cost per ton including extraction, reduction, maintenance, management, general expenditure and depreciation, was £2 2s. 7·78d. per ton; and this leaves a profit of £5 per ton.

Arrangement of Leaching-vats at the Ivanhoe Mine.—At the Ivanhoe mine, the leaching-vats for the potassium-cyanide process are arranged in two tiers, so that the sands from the upper vats fall through a few feet of air-space into the lower. There are 16 80-tons vats, 8 of them on the higher level, and the other 8 vats some 5 feet immediately below. The upper set are fitted with Butter revolving distributors, and serve as settling-tanks, as well as leaching-vats, about 40 per cent. of slimes being taken out in the process of filling, as already described. It is claimed for this arrangement of two tiers of vats that it saves 2 days in the duration of the leaching process—4 days in each vat, or 8 days in all, being found sufficient, instead of 10 days, which is the usual period under the ordinary arrangement. The action of the potassium-cyanide solution is facilitated by the admixture of oxygen received in the passage of the sands from the upper to the lower vats, and also by the loosening of the material thus effected. A solidified condition of the sands hinders their thorough permeation by the potassium-cyanide solution.

In October, 1898, 120 to 140 tons of sands were being treated daily in this cyanide-plant with a staff of 13 men. Filter-presses were being erected for the treatment of the slimes.

It is perhaps worth noting that they were about to add another 30 feet length of canvas tables below those already existing, by which they hoped to catch a further 2 to 3 dwts. of free gold.

Mill at Lake View South Mine.—At the Lake View South mine there is a mill, where they undertake the treatment of ore sent by outside parties. To it comes much of the free-milling ore from the surface diggings and shallow workings at Kanowna, a gold-mining camp of considerable importance, situated 12 miles north-east of Kalgoorlie, and connected with it by rail.

In the Lake View South mill, there are five floors at succeeding levels a few feet below each other:—(1) Stamps and amalgamation-tables on the highest level, (2) grinding-pans, (3) frue-vanners, (4) combination-pans, and (5) settling-pans; and the product flows automatically through the whole.

The ore, having been first sized over a "grizzley" and the larger pieces broken by a Blake crusher, falls from the ore-bin down chutes to Challenge self-feeders, through which it is introduced under the stamps. There are 20 heads of stamps, weighing 900 pounds each. The mortar-boxes are fitted with inside copper-plates; and with coarse screens allowing a rapid discharge. The water-supply is heated by the exhaust steam from the engine driving the stamps, as the use of heated water is found to increase the amalgamating action of the mercury. The copper amalgamation-tables are 11 feet long, and at every 17 inches there is a step or drop of about 2 inches, and a metal bar fixed transversely across the table above the step.

The flowing pulp comes against the metal bars and falls down the steps. Thus the solid particles are turned over and over again, and the free gold is brought into intimate contact with the mercury on the surface of the plates. An adjusting screw at the bottom of these tables enables their slope to be varied to suit different kinds of ore.

From these amalgamation-plates, the pulp is conveyed along launders, which are fitted with corrugated copper riffles for catching the heavier particles of gold, to 6 Watson-and-Denny grinding-pans standing on a floor 5 feet below the copper-plates. They grind the pulp still finer and catch some of the float-gold.

The discharge from these pans is carried by launders, fitted as before, to 4 frue-vanners on the next floor, 4 feet below. By the frue-vanners, concentrates are separated containing 2 to 3 ounces of gold per ton, which are subsequently treated by cyanidation.

The residue of pulp resumes its downward flow along launders which convey it to Californian grinding and amalgamating-pans, of which there are 4 on the next stage. The discharge from these falls a further 3 feet into 3 settling-pans, each 8 feet in diameter. The refuse-slime flows into settling-pits, from which the clear water is pumped back into the battery storage-tanks.

Frequent assays are made of the escaping slime to find what gold is lost.

Actual figures over 5 months show an extraction of 90·8 per cent. of the total gold-contents. The average assay-value of the ore received, chiefly from Kanowna, was 2 ozs. 3 dwts. 3 grs. per ton, and of the escaping slimes 3 dwts. 23 grs., giving an average extraction of 90·8 per cent.

For treating the concentrates from the frue-vanners, there is a small potassum-cyanide plant consisting of 2 solution-tanks and 2 leaching-vats, with zinc-boxes. The presence of oxide of iron in the concentrates complicates the process. The cost of the cyanide treatment was stated to be 8s. 9d. a ton, and of the milling from 14s. to 15s. a ton.

Mill at the Associated Mines.—At the Associated Mines, the oxidized ore is treated by dry crushing and cyanidation. It falls into a breaker at the top of the mill, and thence into a trommel, which separates the fines from the rough. The fines are raised by a bucket-elevator into a bin, and the rough is delivered by automatic feeders into 4 Krupp ball-mills. After being crushed fine in these, it is raised by the elevator into the bin. Metal trucks, holding about 1 ton of the crushed ore, are filled below the bin through circular canvas spouts. These trucks have a W shaped bottom, and hinged flap-doors at each side to allow of the speedy discharge of their contents. They are run on to a carriage holding 4 or 5 of them placed end to end. This long carriage moves on rails laid along each side of the vats, and is pulled to and fro over the top of them by an endless-rope. By moving a lever connected with an endless belt and fast and-loose pulleys, the attendant can start and stop the carriage immediately at any point. The vats are large, holding 160 tons. By the aid of this overhead travelling-trolley, the contents of the trucks are deposited evenly over the whole area of the vats, and no trimming is required. Two men fill a 160 tons vat in 8 to 10 hours.

The charge stands in the vat under the action of the potassium-cyanide solution for about 10 days. The solid residue from the vats falls into trucks below. Thus they are filled and emptied with a minimum of labour.

In the same building were 3 Huntingdon mills with amalgamation-tables and canvas strakes, but it had not been found necessary to use them for some time.

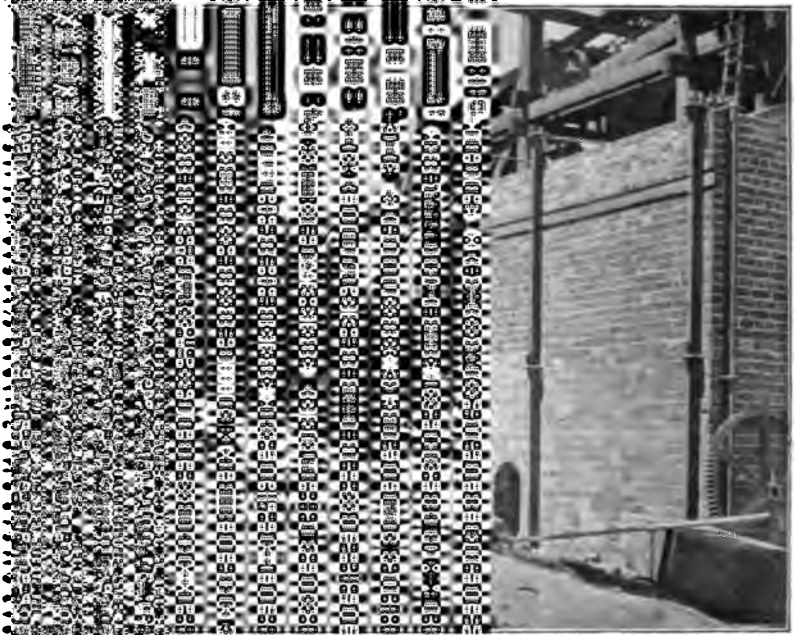
Yield and Cost.—According to the last yearly report of the manager of the Associated Mines, Mr. W. A. Irwin, during the year ended on August 1st, 1898, 20,519 tons of ore had been treated in this mill, and 22,174 ounces of gold obtained from them, at a cost of 18s. 2½d. a ton, including 5s. 6d. a ton for cyaniding. This gives an average yield of 1 ounce 1 dwt. 14 grs. per ton. During the same period, 5,858 tons of sulphide-ore and telluride-ore had been sent away to smelting-works, and 20,440 ounces of gold extracted from them, raising the average yield to 1 ounce 12 dwts. 7 grs. per ton.

Treatment of Sulphide-ores and Telluride-ores.—As regards telluride-ores and sulphide-ores, hitherto the small quantities raised have been sent away for treatment to some of the Australian smelting-works, such as those at Port Pirie, where they have been mixed with the silver lead-ores from the Broken Hill mines, and smelted in their 120 tons smelting-furnaces.

In the United States of America, telluride-ores are successfully treated by roasting and chlorination, but the large admixture in the Boulder ores of lime, and other substances for which chlorine has a strong affinity, renders their treatment by cyanidation a more economical method. At Schemnitz, in Hungary, the tellurides are treated with sulphuric acid to dissolve the tellurium, and the residue is smelted to obtain the gold; but this is an expensive process, and tellurium is of no commercial value. Trials which have been made with the Boulder ores leave little doubt that they can be treated successfully by fine crushing, drying and roasting, and then cyanidation and precipitation in zinc-boxes. The roasting is the crucial part of the process. The ore is sulphide of iron carrying gold, mixed in very varying quantities with telluride of gold and silver, and chemical analyses have shown the presence, in small quantities, of bismuth and mercury also. To get rid of the tellurium, exposure to a mild temperature for some time, not sufficient to melt it, seems to be required, as, if melted, the gold will be

are not amenable to the
ellurium combines with the
s on these lines were being
of 1898.

process to be adopted is as
breakers, dried in a rotary
that the ore slides down it,
end, and is exposed during
a fire (Fig. 6), and then



PLANT AT THE LAKE VIEW

which it falls into trommels.
2 No. 5 Krupp ball-mills,
es to the square inch. The
d thence through automatic
of the feeders, the supply
ed or diminished as desired.
ype known as the Brown
feet wide, built of masonry,
ted ore is cooled in rotary

[illegible] he, and revolving in a bath [illegible] the cylinders. It is then [illegible] ted by a steam-crane into

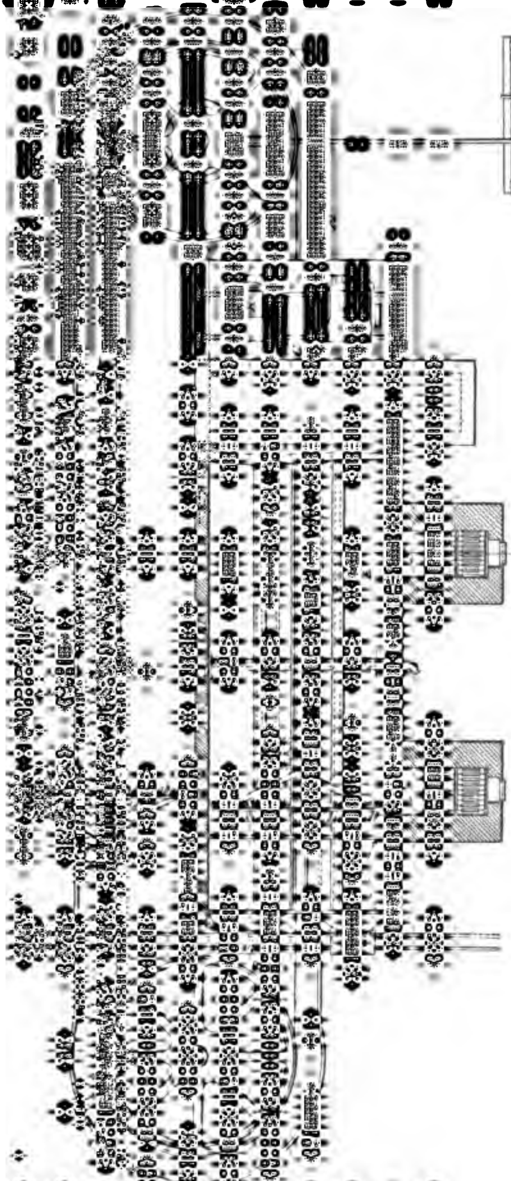


FIG. 7.—PLAN OR HORIZONTAL SECTION OF THE ROPP STRAIGHT-LINE ROASTING-FURNACE.

References: *A*, Furnace-hearth; *B*, Furnace-walls; *C*, Furnace-arch; *D*, Slot; *E*, Conduit; *F*, Fire-boxes; *G*, Rabble-carriages; *H*, Observation-doors; *I*, Swinging Doors; *J*, Rope-sheaves; *J*¹, Flue to Chimney; *K*, Feeders; *L*, Rope; *M*, Rails; *N*, Pulley; *O*, Safety-device or Breaking-pin; *P*, Expansion-space in Hearth; *Q*, Expansion-stays in Walls; *R*, Cars for Finished Ore; and *S*, Rabble-trucks.

[illegible] This plant is designed to [illegible] ipated that its capacity will [illegible] es.

The Ropp Furnace.—At the Association mine, a similar drying and crushing plant is being erected on a large scale to deal with 400 tons daily. Four Ropp straight-line furnaces, 150 feet in length by 14 feet in width, are being built.* The powdered ore falls into the furnace at one end from above. It is spread over a wide, horizontal hearth, and is carried slowly forward over the whole length of the hearth (120 feet and 150 feet in the instances just mentioned) and is stirred continuously, by mechanical rakes or rabbles, whilst it is exposed to the heated products of combustion from the fires (Figs. 7 and 8). These rabbles consist of a number of metal blades, fixed obliquely at intervals of a few inches to a crossbar, which extends from side to side of the furnace, and moves over the surface of the hearth. By this means the ore is stirred about, and pushed forward till it is discharged at the end of the furnace. The rabbles (namely, the crossbar and blades) are attached to carriages, which run on rails in a conduit below the hearth, and which are connected with an endless-rope, the turning-wheels and driving-mechanism being placed outside the furnace. A thin metal plate, moving in a narrow slot in the hearth, connects the crossbar to its carriage below. A series of these carriages (6 or more) follow each other at short intervals. They make the return journey outside the furnace—in the Brown furnace along the top of it, and in the Ropp furnace along one side. This passage through the open air every minute or two cools the heated rabbles. The rope and carriages, which move in a conduit below the hearth, are not exposed to the heat of the furnace. The ends of the hearth are closed by swinging trap-doors, which the rabbles lift as they enter and leave.

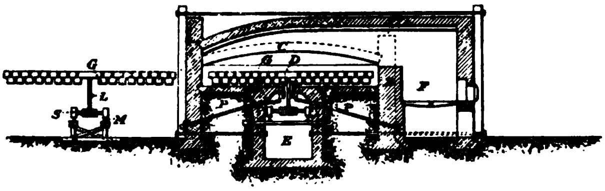


FIG. 8.—CROSS-SECTION OF ROPP STRAIGHT-LINE ROASTING FURNACE, ON LINE *XY* OF FIG. 7.

References: *A*, Furnace-hearth; *B*, Furnace-walls; *C*, Furnace-arch; *D*, Slot; *E*, Conduit: *F*, Fire-boxes; *G*, Rabble-carriages; *H*, Observation-doors; *I*, Swinging Doors; *J*, Rope-sheaves; *J*¹, Flue to Chimney; *K*, Feeders; *L*, Rope; *M*, Rails; *N*, Pulley; *O*, Safety-device or Breaking-pin; *P*, Expansion-space in Hearth; *Q*, Expansion-stays in Walls; *R*, Cars for Finished Ore; and *S*, Rabble-trucks.

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* The Brown is a modification of the Ropp furnace, and occupies less ground area, but the method of roasting is the same in both. The Ropp furnace was patented in the U.S.A. by Mr. Alfred Ropp on January 1st, 1895, and is now largely used in Australia.

The duration of the roast depends on the length of the hearth and the speed at which the carriages travel.

Statistics.—The following table shows the output of the eight leading (estimating them by their produce) mines at the Boulder during the year 1898, their total produce of gold amounting to 390,691 ounces. The figures are taken from the returns compiled by the West Australian Chamber of Mines. During the same period, the total production of gold of Western Australia was 1,050,182 ounces, valued in the official returns at £3,990,693, or £3 16s. per ounce.

Leases.—Under the Gold-fields Act of 1895 (Western Australia), serious difficulties arose in connexion with the conflicting claims of the leaseholder and of the alluvial miner. Each was claiming a legal right to work the same ground, and the law-courts found it difficult to decide, amidst the varying definitions of mining authorities, what was "alluvial." Companies who were spending a large amount of capital on the development of their leaseholds reasonably objected to the presence of the alluvial miner, digging to an uncertain depth on the surface of their holding. The alluvial miner, on the other hand, who had borne the heat and burden of the day before the advent of the capitalist, felt that he was unjustly used in being turned off the premises as a trespasser. Feeling ran so high that the Premier, Sir John Forrest, on the occasion of a visit last year to Kalgoorlie, was mobbed and rudely assaulted by a crowd of miners, who seemed to regard him as a friend of the capitalist.

The legislature recognized that they had made a mistake in allowing a dual title to the same property, and last autumn they passed an amending Act (assented to October 28th, 1898), which settles the matter in favour of the leaseholder. By clause 11 of that Act, it is enacted that "after the granting of any lease, the lessee shall have the exclusive privilege of mining on the land demised and every part thereof." Rumours of these conflicting claims probably account for the doubts which exist in some minds at home about the rights of gold-mine leaseholders in Western Australia. This amending Act ought to remove these doubts. Now, the rights of tenure under which English companies hold mining leases in Western Australia appear to be as secure as in most other parts of Her Majesty's dominions.

Terms of Leases.—Leases are granted for a term of 21 years. The question of renewal has not yet arisen, but no doubt the rights of lease

OUTPUT OF THE PRINCIPAL PRODUCING KALGOORLIE GOLD-MINES (EAST COOLGARDIE GOLD-FIELD) DURING THE YEAR 1898.

Name of Mine.	Total Gold including Produce of Ore Shipped to Smelters.	Ore Crushed in Mill.					Tailings Cyanided.					Slimes.					Concentrates.			
			Gold Recovered.		Yield per Ton.			Gold Recovered.		Yield per Ton.			Gold Recovered.		Yield per Ton.			Gold.	Yield.	
	Ounces.	Tons.	Oz.	Dwt.	Oz.	Dwt.	Tons.	Oz.	Dwt.	Oz.	Dwt.	Tons.	Oz.	Dwt.	Oz.	Dwt.	Tons.	Oz.	Oz.	Dwt.
Lake View Consols ...	102,667	67,261	60,685	19	0	18·0	42,422	29,177	2	0	13·7	17,837	6,206	19	0	6·9	215	3,204	14	18
Great Boulder	84,402	41,043	84,401	10	2	1·1	—	—		—		—	—		—		—	—	—	
Associated	43,369	28,431	40,969	16	1	8·8	2,400	1,200	0	0	10·0	—	—		—		—	—	—	
Ivanhoe...	51,660	27,110	41,015	6	1	10·3	14,829	10,644	18	0	14·4	—	—		—		—	—	—	
Hannan's Brownhill ...	50,962	23,826	50,961	13	2	2·8	—	—		—		—	—		—		—	—	—	
Boulder Perseverance	17,387	14,739	17,387	9	1	3·6	—	—		—		—	—		—		—	—	—	
North Boulder... ...	9,829	10,209	9,829	5	0	19·3	—	—		—		—	—		—		—	—	—	
Golden Horseshoe ...	*30,415	9,299	22,084	9	2	7·5	3,555	6,951	13	1	9·1	—	—		—		—	*	—	
Totals	390,691	221,918	327,335	7	1	9·5†	63,206	47,973	13	0	15·2†	17,837	6,206	19	0	6·9	215	3,204	14	18

* Including concentrates.

† Average yield per ton.

holders will be protected, when the term of their present leases expires. A leaseholder has the right to surrender his lease "at any time with the consent of the Governor," and the clause of the Act giving this right continues, "and any such gold-mining lease may, with the like consent, be renewed."

Government Reservations.—Government reserves to itself the right to take possession of and resume, without compensation to the lessee, such parts of the surface demised as may be necessary from time to time for gas-mains or water-mains or for public buildings, high-roads, railways, or railway-stations and tramways. Also the right, without compensation to the lessee, to make and use in, on or under the area demised, "any works for freeing and keeping free from water or for conveying water to any other lands or mines for mining purposes, or for supplying any other mines with fresh air, or for effectually working any other mines, or for any public purpose whatever." And lastly, the right to determine the lease, if the lessee at any time shall fail to use the land demised "*bonâ fide* for the purpose for which it has been demised," or for any breach of covenant, the final decision to be left to the Governor.

Area and Shape of Leases.—The area demised in a lease is 24 acres. Such area shall be measured in the form of a parallelogram wherever practicable, and the maximum length shall not exceed twice the width across the line of reef or lode.

The same company may hold several areas. The yearly rental is 20s. per acre or fraction thereof. The rents of all leases are calculated from January 1st to December 31st, and may be paid at any time up to January 31st without fine. If not paid until February, a fine of 10 per cent. is added, and this is increased to 15 per cent. if payment is delayed until March. If not paid before March 31st, the lease is voidable at the will of the Governor.

Labour Conditions of Leases.—Certain labour-conditions are attached to leases. The ground must be "efficiently" and continuously worked on every working-day (not being a bank or public holiday), except during such period of exemption from work as the Warden or Minister may grant. "Efficiently worked" means that 8 hours *bonâ-fide* work shall be performed by the complement of men required by the regulations on every working-day except Saturday, when 4 hours' work will be considered sufficient. The complement of men specified is one man (at least) for every 6 acres or fractional part thereof. For good cause shown, a Warden may grant a lessee exemption from labour-conditions for any period not exceeding one month. For a longer period, application must be made to the Minister of Mines. No Asiatic or African alien is allowed to be employed as a miner, or in any capacity whatever in or about a mine. This regulation is directed against the Chinese and Japanese, who, if allowed free scope, would swarm over Australia and undersell the native labour.

In conclusion, the author wishes to acknowledge his obligations to the managers and officials of the various mines that he visited for much information received from them.

Mr. G. J. **Binns** said that he was not acquainted with Western Australia, but in many of the colonies where English people were gold-mining, the Government regulations did not conduce to happiness among the capitalists. It appeared that the difficulties of mining were very great, and the scarcity of water must be a very great drawback to the economical working of the mines. Wages seemed to be high.

Mr. J. J. **Sandeman** (London) said that there was one point about mining in Western Australia, which he thought certainly mining-engineers ought to know, namely, that the sanitary conditions were so abominable in that colony that typhoid fever raged there as a perfect pestilence. It carried off hundreds of men who went to the mines, and it was caused by the gross carelessness of the people who lived in the colony, as there was an entire neglect of sanitary arrangements. He believed that the Government was beginning to take notice of the matter, but it was certainly a serious matter in a mining country whenever any disease of that kind existed.

The mining laws were very good for the Colonial Government, but for no one else. In most of the colonies, if they found a stratum only 2 inches wide, they had to locate a claim of 20 or 40 acres of land to work it, and pay rent of 5s. per acre upwards. He had lived many years in the United States of America, and had seen the excellent way in which their mining laws worked, and the facilities that they gave for opening up the country. He did not consider any of the mining laws of the colonies with which he was familiar such as to induce a prospector to go thither from this country. In most of the colonies, they would allow claim-holders to dispense with the labour clauses under certain conditions, which proved conclusively that the labour clauses were not fair, or they would not make a proviso by which they could upset them.

Mr. **James McMurtrie** (Bath) said that he would be glad if a little more information could be given as to the geological surroundings of the gold-mining region. He understood that the means of transport were very imperfect. It did not appear on the face of the paper what means there were of getting materials to the mines or conveying the produce from the mines when fit for the market.

Prof. H. **Louis** (Newcastle-upon-Tyne) congratulated Mr. Bulman on giving one of the most able accounts that he had read of the Kalgoorlie gold-fields.

Mr. C. **Pamely** (Chepstow) asked whether the different lodes of this gold-field had been sufficiently worked for any one to form an opinion of their number and whether they were all named. Can the lodes which prove so rich in the notable gold-mines be identified throughout a considerable area in other less developed mines, and are they vertical, or nearly so there, as far as proved? While the increased value of shares in the leading Kalgoorlie mines during the last 6 months appeared to show that the deposits maintained their high value, or are even enriched in depth, could any determination be made of the prospects of the whole gold-field in which a number of mines were as yet yielding no return? Even if the lodes were traceable, their pockety nature seems to preclude any estimate of the value of a particular undeveloped lease situated only a little distance away from the vicinity of the proved valuable mines of the district. The success of the few would, of course, stimulate and encourage the carrying-on of mining operations, and it would be helpful in directing these if fuller particulars of the payable ore-bodies could be given in the paper.

Mr. H. F. **Bulman** said that he was not aware that the health of the people was so bad; it was considered a healthy climate. There was a want of water, but when they got the supply which they expected in about a year, this difficulty would be removed. The most recent information about the geology of the district, of which he was aware, was contained in the paper by Mr. Edward F. Pittman, already mentioned. According to that authority, the elevated table-land on which Coolgardie and Kalgoorlie stand is composed principally of "granites and crystalline gneisses, with occasional belts of metamorphic schists, and dykes of diorite or other hornblendic rocks." In the neighbourhood of the gold-bearing Boulder area, the country consists of plains which are covered by surface-deposits of sand, gravel, and travertine. Hence the geological character of the strata can not be determined without boring. The rocks of the Boulder tract, which has been explored by mining, are eruptives, which had undergone great alteration.

A railway connects Kalgoorlie with Fremantle and Albany, the two chief ports of Western Australia, and with Perth, the capital; and another railway joins Kalgoorlie to the Boulder mines, a distance of 4 or 5 miles. These railways belong to the Government, and are efficiently worked.

The exceptionally rich telluride-ores and sulphide-ores which are wrought in some of the Boulder mines are confined to a small area, so far as is yet known. There were reports, last year, that similar ores had been found some 25 miles distant in both directions along the same line of strike, but these reports have not been confirmed. As may be gathered from his (Mr. Bulman's) paper, the gold-bearing belts of the Boulder mines are not lodes with well-defined walls running uniformly for long distances. Mines bordering on each other vary immensely in the value of their ore, and it is quite a mistake to estimate the probable value of an unproved mine by the known richness of another, even in the immediate vicinity. Gold-mining in Western Australia is in its infancy, but its unusually vigorous infancy points to a robust maturity. Gold has been found over a very wide area, and it would be remarkable if the rich ores should be limited to the small patch yet proved, which forms the subject of his (Mr. Bulman's) paper.

The PRESIDENT (Mr. J. A. Longden) said that the members were indebted to Mr. Bulman not only for his excellent paper, but also for the interest which he took in the Society of Mining Students, of which he had been for some time President, and which was an excellent feeder for their more adult society.

Mr. W. J. ORSMAN read the following "Further Notes on Safety-explosives":—

FURTHER NOTES ON SAFETY-EXPLOSIVES.

By W. J. ORSMAN.

In a recent paper,* the writer showed that during the period of 11 years from 1887 to 1897 inclusive there were officially recorded 34 explosions of gas or coal-dust due to explosives, resulting in 671 deaths. Tables I. and II. record in chronological order the situation of each of these explosions.

TABLE I.—LIST OF FATAL EXPLOSIONS OF FIRE-DAMP AND COAL-DUST CAUSED BY EXPLOSIVES DURING THE 11 YEARS FROM 1887 TO 1897 INCLUSIVE, EXTRACTED FROM THE ANNUAL REPORTS OF H.M. INSPECTORS OF MINES.

1.—GUNPOWDER.

No. of Accident.	Year.	Name of Mine.	Mines-inspection District.	No. of Deaths.
1	1887	Walker	Newcastle-upon-Tyne	1
2	"	Walker	Newcastle-upon-Tyne	8
3	"	Brynn (Lilly Lane)	Liverpool	3
4	"	Ffrwd	Liverpool	3
5	"	*Udston	Scotland, East	73
6	1888	St Helen's	Newcastle-upon-Tyne	30
7	1889	Bothwell Park	Scotland, West	1
8	1890	Morfa	South Wales	87
9	1891	†Ashton Moss	Manchester	2
10	1892	Coxlodge	Newcastle-upon-Tyne	1
11	"	Gartshore	Scotland, West	1
12	1893	Dunston	Newcastle-upon-Tyne	2
13	"	Camerton	South Western	2
14	1894	Bankhouse (Charters)	Manchester	1
15	1895	Newmarket, Haigh Moor	Yorkshire	2
16	"	Blackwell, A Winning	Midland	7
17	"	Timsbury	South Western	7
18	"	Malago	South Western	2
19	"	Morlais Vale	South Wales	2
20	1896	Brancepeth	Durham	20
21	1897	Darngavil	Scotland, East	2
			Total	257

* Mr. R. Moore, H.M. Inspector of Mines, stated in his report that: "A shot fired surreptitiously ignited the gas." (Page 44.)

† Mr. J. Dickinson, H.M. Inspector of Mines, stated in his report:—"The explosive ordered to be used was securite, but from the indications left after the shot powder was apparently used instead." "The lighting was by fuze, ignited by wire heated through a small hole in the shot-firing lamp." (Page 10.)

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* "Safety-explosives," *Trans. Inst. M.E.*, vol. xvii., page 54.

TABLE I.—*Continued.*

2.—TAPE-FUZE.

No. of Accident.	Year.	Name of Mine.	Mines-inspection District.	No. of Deaths.
1	1890	Thorncliffe	Yorkshire	2
2	„	Hanley	Staffordshire, North ...	1
3	1891	Moss Hall	Liverpool	2
4	1895	Lea Green	Liverpool	1
5	1896	Tylorstown	South Wales	57
6	1897	Bothwell Park	Scotland, West	1
7	„	Calder	Yorkshire	3
			Total	67

3.—NITRO-GLYCERINE EXPLOSIVES.

No. of Accident.	Year.	Name of Mine.	Mines-inspection District.	No. of Deaths.
1	1887	*National	South Wales	39
2	1889	†Hebburn	Newcastle-upon-Tyne ...	6
3	1891	‡Apedale	Staffordshire, North ...	10
4	1894	*Albion	South Wales	290
			Total	345

4.—OTHER HIGH EXPLOSIVES (TONITE).

No. of Accident.	Year.	Name of Mine.	Mines-inspection District.	No. of Deaths.
1	1890	Shelton	Staffordshire, North ...	1
			Total	1

* Gelatine Dynamite. † Gelignite with Roburite. ‡ Gelignite.

TABLE II.—SUMMARY OF FATAL EXPLOSIONS OF FIRE-DAMP AND COAL-DUST DUE TO EXPLOSIVES DURING THE 11 YEARS FROM 1887 TO 1897, INCLUSIVE.

Name of Explosives.	Explosions.		Deaths.	
	No.	Percentage of Total.	No.	Percentage of Total.
Gunpowder	21	61·77	257	38·30
Tape-fuze	7	20·59	67	9·98
Nitro-glycerine explosives ...	4	11·76	345	51·42
Other high explosives	1	2·94	1	0·15
Uncertain	1	2·94	1	0·15
Totals	34	100·00	671	100·00

From Tables I. and II. it will be seen that, although the nitro-glycerine explosives were responsible for the largest number of deaths, namely, 51·42 per cent., most of the explosions were due to gunpowder, namely, 61·77 per cent.

It is difficult to obtain a complete list of explosions for the preceding years for all districts, but it may suffice if one district be taken, for which there are official records, namely, the Liverpool mines-inspection district (Table III.).

TABLE III.—LIST OF FATAL EXPLOSIONS OF FIRE-DAMP AND COAL-DUST CAUSED BY EXPLOSIVES IN THE LIVERPOOL MINES-INSPECTION DISTRICT FROM 1871 TO 1887 INCLUSIVE.

No. of Accident.	Year.	Name of Mine.	Where Situate.	No. of Deaths.	Explosive Used.
1	1871	Moss Pits	Wigan	72	Gunpowder.
2	1873	Brynn Hall	,, ...	6	,,
3	,,	Wynnstay	,, ...	7	,,
4	,,	Hanmer	,, ...	1	,,
5	1874	Ince Hall	,, ...	15	,,
6	1875	Hafod	,, ...	3	,,
7	1876	Orrell	,, ...	2	,,
8	,,	Moss	,, ...	1	,,
9	,,	Brynn Hall	,, ...	1	,,
10	,,	Swan Lane	,, ...	1	,,
11	1877	Pemberton	,, ...	36	,,
12	1880	Bersham	,, ...	9	,,
13	1881	Park Lane	,, ...	2	,,
14	,,	Tawd Vale	Skelmersdale ...	1	,,
15	,,	,, ...	,, ...	1	,,
16	1883	Mains	Wigan	2	,,
17	1885	Strangeways Hall ...	,, ...	2	,,
18	,,	Taylor Pit	,, ...	1	,,
19	1887	Lilly Lane	,, ...	3	,,
20	,,	Ffrwd	,, ...	3	,,
			Total ...	169	

Table III. shows that in the Liverpool mines-inspection district alone during the 17 years from 1871 to 1887 there were at least 20 explosions, causing 169 deaths, all due to gunpowder. In 1888, safety-explosives were first introduced into this district, and since then there have only been 2 explosions with tape-fuze, resulting in 3 deaths. No fatal explosions have occurred with other explosives.

Since January, 1898, several new forms of gunpowder have been produced, and passing certain tests at Woolwich have been placed on the permitted list. The question is constantly being put, What is the difference between these powders and the old blasting-powder? Table IV. has been prepared from the published compositions.

It will be seen from Table IV. that all the new blasting-powders (with the exception of oxalate blasting-powder) contain the same, and no other ingredient than the older forms of blasting-powder. Any factor of increased safety must be looked for either as the result of the proportion of the ingredients taken or in the mechanical methods of

TABLE IV.—COMPOSITION OF THE VARIOUS FORMS OF GUNPOWDERS UPON THE PERMITTED LIST COMPARED WITH BLASTING-POWDERS.

Name of Explosive.	Saltpetre (Nitrate of Potassium).	Charcoal.	Sulphur.	Oxalate of Potassium.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Black artillery-powder ...	75	15	10	—
Brown cocoa-powder (artillery)	79	18	3	—
Blasting-powder, old ...	65	20	15	—
Argus-powder	79 to 82	17 to 20	1 to 0·5	—
Earthquake-powder ...	78 to 81	19 to 22	0·12 or less	—
Elephant brand	74 to 76	14½ to 15½	9 to 11	Fitted with plug at end.
Oxalate blasting-powder ...	69 to 73	12 to 15½	2 or less	13½ to 16½

manufacture. With artillery service-powders, the proportion of sulphur was reduced from 10 per cent. in black powder to 3 per cent. in brown cocoa-powder with the result of producing a powder which should commence to burn comparatively slowly and so overcome the *vis inertiæ* of the projectile without throwing too great a strain on the gun. In argus and earthquake powders, the sulphur is reduced to 1 per cent. or even less. We can hardly imagine, however, that any increase of safety could be produced by decreasing the speed of explosion. On the other hand, it is generally accepted that the reverse is the case. Again, the temperature of explosion of the new blasting-powders cannot be less than that of the old powders, and the solid products of combustion (*i.e.*, the fumes) will be even greater than that of old blasting-powder on account of the greater proportion of the non-volatile potassium compounds. We must therefore look for some further causes to account for any difference of behaviour on explosion:—

(1) *Mechanical Condition of the Powders.*—In the new blasting-powders, the ingredients are more carefully selected and more thoroughly incorporated. This last condition would help to ensure thorough ignition of all the grains of the explosive at the moment of explosion; while with the old form of blasting-powder, the ingredients not being ground into a thoroughly fine state of division and being badly incorporated, particles of material might be projected in a non-exploded but burning condition.

(2) *Gaseous Products of Combustion.*—Analysis of the gases produced by the explosions of old blasting-powder showed the production of that noxious gas—sulphuretted hydrogen (H_2S) and carbon monoxide (CO). These gases are very inflammable, and mixed with air form explosive mixtures easily ignited at a low temperature. With the new blasting-

powders only a trace, if any, of sulphuretted hydrogen would be found, and experiment has yet to determine what volume of carbon monoxide is produced on explosion. Apart from the explosive itself, there may be some virtue in particular forms of stemming that may be used.

Oxalate blasting-powder contains a foreign ingredient in the form of oxalate of ammonia, which is non-explosive in itself and does not add to the explosive force.

Elephant-brand powder consists of high-grade powder, similar in composition to sporting-powder, with the addition of a plug at one end containing oxalate of ammonia. This plug acts as a safety-stemming, which would probably be useless if the cartridge were placed in the hole wrong end about. And, moreover, from the form of the cartridge, the safety element can easily be removed.

In both the abovenamed blasting-powders, the heat of combustion decomposes the oxalate of ammonia and the resulting temperature is lowered. A bad effect must ensue in both cases, and very objectionable fumes are apt to be produced.

After all, are the new forms of blasting-powder as safe as is claimed for them? Without hesitation the writer says that they are not, and their introduction into mining districts where gunpowders were condemned and safety-explosives used is a step backward in the safe working of coal-mines.

Experiments have already shown, and experience in firing in mines will very soon show, if it has not already done so, that although these blasting-powders may, under certain conditions be safer than those that have not passed the Woolwich tests, they are infinitely inferior to certain safety-explosives that have been in constant use during the past 10 years.

The President said that the meeting might be interested to know that the other day he had two heaps of slack put on the surface—the finest and driest that they could obtain from the screens. In one heap they fired a shot of blasting-powder and in the other of amvis. The flame from the gunpowder shot was enormous, while with amvis there was no flame whatever. Both shots were fired by electricity. He had used blasting-powder for many years, and so far as he knew had not had an explosion from it; but he had no doubt that blasting-powder was less safe than any of the permitted explosives.

Mr. **Arnold Lupton** (Leeds) said that the country was under a great debt of gratitude to the skilful inventors and experimentalists who had brought out new explosives. Simply to have forbidden the use of explosives in mines would have increased the cost of mining without decreasing the number of accidents; because the increased number of men necessary to do the work without explosives would add also to the number of deaths which would have followed from other accidents, and have been such that the total number of deaths from mining would not have been reduced. Some 20 years ago, the idea of safety-explosives would have been considered impracticable, and now it was an everyday business.

Mr. **L. T. O'Shea** (Sheffield) said that the method of combustion which brought about the explosive effects of blasting-powder was one of great danger, and no matter what low explosives would be invented, he was sure that they would always be a great source of danger. One of the points of safety of high explosives was that they were decomposed by detonation and not by combustion. He could scarcely accept Mr. Orsman's statement that he could hardly imagine that any increase of safety would be produced by decreasing the speed of explosion. Mr. Heise had made experiments and pointed out that when the shattering power of a high explosive was reduced the safety of that explosive was considerably increased as measured by the weight of explosive which was necessary to bring about ignitions of coal-dust and gas. With regard to the use of safety-stemming, it had been pointed out, chiefly by the French Commission on the Use of Explosives in Mines, that in all probability it would be very ineffective in its action, which in most cases depends on the absorption of heat consequent on certain chemical decompositions, and the time occupied by the explosion was too short to allow these decompositions to take place, and this being the case the use of safety-stemming would probably lead to a sense of false security. The tests which were carried out at Woolwich were made on too small a scale to be of practical value to those who used explosives in coal-mines.

Prof. **H. Louis** (Newcastle-upon-Tyne) said that Mr. Orsman had divided explosives into two classes—low explosives without detonation, and and high explosives with detonation. High explosives fired by detonators were responsible for 5 explosions, while tape-fuze was responsible for 7. There were 12 explosions due to the use of high explosives, as against 21 with low explosives; in round numbers half as many.

Mr. H. A. **Krohn** (London) said that it was almost impossible to obtain any accurate data as to the relative quantities of gunpowder and high explosives used during the last 10 or 11 years. Gunpowder, during these years, was used in all classes of mines, whether fiery or non-fiery, whereas it was the case, so far as his knowledge went, that explosives of the ammonium-nitrate or safety class were never used unless there was risk of explosion from coal-dust or gas. This bore very strongly on the question of the relative quantities of the two explosives used. Again, Prof. Louis, in making his comparison of the number of accidents which happened, classed tape-fuze in connexion with high explosives generally. That might or might not be, but he thought that Mr. Orsman, in his paper, was not drawing a comparison between the relative safety of high explosives as a class on one side and gunpowder on the other, but that he directed attention to a particular explosive on one side and a bad explosive on the other. Mr. Orsman showed that the use of ammonium-nitrate explosives fired by electricity was the greatest safeguard that they could have against an explosion of coal-dust or gas in coal-mines. Tape-fuze, even if used to ignite ammonium-nitrate explosives, could not be taken as casting any discredit on the explosive with which it was used, for it was simply gunpowder itself. He thought, therefore, that Prof. Louis, instead of grouping tape-fuze with high explosives should have grouped it with gunpowder.

Mr. **Arnold Lupton** (Shirebrook) suggested that The Institution of Mining Engineers should take in hand the testing of safety-explosives for use in mines. as the results of the Government tests at Woolwich were not considered satisfactory, and that the Institution should give its own certificate, in addition to the Government certificate, for the benefit of coal-owners.

Mr. H. **Hall** (H.M. inspector of mines) said that Mr. Orsman's paper was very significant in one direction, namely, it showed that much greater safety was secured by using permitted explosives, more especially those of the ammonium-nitrate class, than gunpowder. Mr. Orsman had given statistics dealing with the last ten years, ending with 1897. But since that time, statistics still more convincing as to the great advantages of high explosives over gunpowder had been obtained. Anyone referring to the official statistics of accidents during the years 1897 and 1898 would find that they nearly all occurred in districts where open lights were used. consequently where the Explosives Order hardly applied. In Scotland open lights were generally used, and in the two mines-inspection districts, there were upwards of 100 explosions of fire-damp last year, while in other districts they dwindled down to 2 or 3. It would appear that explosions of fire-damp had almost disappeared altogether in those mines-inspection districts where high explosives had been universally introduced. The Explosives Order only came into force in July, 1897, about 2 years ago. In these 2 years, 46 people had been killed by explosions of gas, and in the best single previous year there were 49, and the best two consecutive previous years showed 127 as against 46 deaths in 1897 and 1898. He thought that the Mining Institutes might have helped towards this result, and that they should not have waited for the Government to take action in the matter.

Mr. C. C. LEACH (Seghill), with reference to the remark about mines where candles were used not coming within the Explosives Order, said that they all came within that Order, unless the pits were naturally wet throughout. The North of England Institute of Mining and Mechanical Engineers investigated the matter long before the Government, and had always been first in safeguarding human life. In the North of England, there were many pits using high explosives before the Act was introduced or passed.

Mr. M. WALTON BROWN (Newcastle-upon-Tyne) said that the North of England Institute of Mining and Mechanical Engineers appointed a committee in 1888 to make investigations and report upon the subject of safety-explosives. The explosives testing-plant designed by their committee had been adopted at the Home Office testing-station, and, in addition, the recommendations of the committee had been generally adopted by the Home Secretary. These experiments showed that ammonite, ardeer-powder, bellite, carbonite, securite and westfalit were less liable than blasting-powder to ignite inflammable mixtures ; and that ignitions of air and coal-dust—with or without the presence of fire-damp—could be obtained in the presence of a smaller quantity of coal-dust than had hitherto been supposed to be necessary. He suggested that the composition of the committee appointed by the Home Office to test explosives for use in mines should be reconsidered, and that mining engineers—equal in number to the official representatives—should be added to it.

Mr. W. J. ORSMAN, referring to the President's experiments on the surface with coal-dust, said that an ignition of coal-dust was readily produced by any of the new gunpowders, and therefore the new gunpowders were not safer than the old. Mr. O'Shea had taken exception to his statement that the quicker the speed of explosion the safer the explosive. In the first place, mixtures of fire-damp and air required a certain time for ignition, and it was proved by a foreign commission that marsh gas was ignited after 2 seconds contact with flame. German inventors had been able to slow down the detonation of an explosive by adding a foreign substance, but that only introduced incomplete combustion. It was a fact that with retarded detonation incomplete combustion ensued, and in that way they could make an explosive which would not ignite fire-damp and air, but at the same time it was liable to miss-shots. Prof. Louis tried to prove from Table II. a strong case for gunpowder. He thought that Prof. Louis was taking a wrong view, because he (Mr. Orsman) did not regard all high explosives as safety-explosives, as high explosives and safety high explosives were two very different things. Gunpowder should certainly include tape-fuze; and with dangerous gunpowder they should assuredly include such explosives as gelatine-dynamite, dynamite, and even gelignite, which had proved treacherous and unsafe. Safety high explosives had a better record than old-fashioned gunpowder and nitro-glycerine compounds. During the whole period in which detonating high explosives of the ammonium-nitrate class had been made, there had not been a single fatal accident in any part of Great Britain where the shot had been fired electrically, but there had been cases where tape-fuze had been used and gas had been fired and lives had been lost. Prof. Louis had made some comparisons between accidents produced by gunpowder and those from safety high explosives, and Mr. Krohn pointed out that safety high explosives had only been used in places where gunpowder could not be—that is, in dangerous places. No matter how far they might increase the ventilation and remove the gas, coal-dust was always present, and any explosive which would fire coal-dust must be dangerous to use. There had been more accidents in collieries working the Wigan nine-feet mine than in all the rest of the seams in the Lancashire coal-field. The reason was that, in this particular seam, instead of holing at the bottom the collier holed at the top and the coal was blasted from the floor. The shot was made near the level of the floor, and the flame came in contact with the floor itself, on which a large quantity of coal-dust was lying.

Mr. DONALD M. D. STUART (Bristol) wrote that these "Further Notes" contained a restatement of Mr. Orsman's preceding paper, but without correction of the mistakes discovered during its discussion.

The notes were founded upon two suppositions that—(*a*) High explosives and gunpowder were used in an equal number of shots in the 11 years ending 1897; and (*b*) the reduced number of explosions from shot-firing was due to the partial change from gunpowder to high explosives. The first supposition was contrary to the facts, and the second appropriated the results of the research and labour of mining engineers; both were therefore untenable. In addition, the tables given to support the suppositions did not correctly represent official records, as explosions were charged against gunpowder that were reported as doubtful or due to other causes; and the fact that nitrate-of-ammonium explosives are recorded to have been involved or to have caused some of these disasters is omitted. The following were examples:—

Table I. (1), gunpowder, Udston colliery explosion, with a footnote. "Mr. R. Moore, H.M. inspector of mines, stated: 'A shot fired surreptitiously ignited the gas.'" The extract does not give the name of the explosive used in the shot, consequently there is no evidence for debiting gunpowder with the explosion. Moreover, the facts brought to light in the recent discussion are omitted. It had been already shown* that the explosion was judicially investigated, when the Commissioners (Mr. J. Dickinson, H.M. inspector of mines, and Mr. C. C. Macconochie, advocate) had before them Mr. R. Moore's opinion as to a shot, with other opinions to the contrary, and reported:—"That on various of the bodies were found matches ignited and unignited, tobacco, pipes, lamp-keys and nails;" and that in their judgment the explosion "was primarily caused by the ignition of some quantity of fire-damp at an open light or by being drawn through the gauze of a Scotch safety-lamp."†

The fact is omitted that the St. Helen's colliery explosion occurred 12 hours after a shot was fired, and was caused by reversing the ventilation of the mine, which carried accumulated gas on the fire.‡ The case is further illustrated by an explosion at a fire in Podmore Hall collieries. Here it was decided to alter the ventilation so as to bring accumulated gas down over the fire. The fan was suspended, but 40,000 cubic feet of air per minute continued to circulate naturally, and a stopping was put in the return-airway, which turned the ventilation backward. An explosion occurred 9 hours after the stopping was completed, and wrecked the mine.* Explosion necessarily follows the contact of explosive gas and unprotected flame, whether it be flame of lamp, candle, or fire; but when such explosion follows a deliberate change of ventilation, which brings gas into contact with an unprotected flame known to lie in the path of the gas, the cause is in the act that produced the ignition, and not in the means of the ignition, much less the origin of the flame.

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* *Trans. Inst. M.E.*, vol. xvii., page 65.

† *Report upon the Udston Colliery Explosion*, pages 14 and 21.

‡ *Report upon the St. Helen's Colliery Explosion*, page 6.

Morfa colliery explosion. Mr. J. T. Robson, H.M. inspector of mines, reported:—"It should be mentioned that there was no positive evidence of a shot having been fired at or about the time of the explosion."† This fact was also again omitted.

These three explosions, one due to an open light or lamp, another to reversing the ventilation, and the third to an unknown cause, with no evidence that a shot was fired, represent 190 of the 257 deaths charged to gunpowder, reducing the number to little more than one-fourth.

Mr. Orsman's treatment of other explosions may be illustrated by the following examples:—

Table I. (1), gunpowder, Gartshore colliery explosion, upon which Mr. J. M. Ronaldson, H.M. inspector of mines, reported, saying:—"Milligan fired a shot, and it appears when lighting the fuze he ignited an accumulation of fire-damp."‡

Table I. (2), tape-fuze, Moss Hall colliery explosion, of which Mr. H. Hall, H.M. inspector of mines, reported:—"A shot of roburite was being fired by ordinary fuze, when some gas which had collected fired at the flame from the fuze." §

Table I. (2), safety-fuze, Lea Green colliery explosion, of which Mr. Hall also reported as follows: - "The roburite was being fired by tape-fuze, and the instant the shot-lighter ignited the fuze, the fuze ignited some gas." ||

These three explosions are reported as equally caused in the act of igniting the shots; but the Gartshore colliery explosion, where the explosive used is not reported, is charged against gunpowder; and the other two explosions in which roburite is recorded as used, are charged against tape-fuze, and roburite omitted from the tables. This is obviously unequal and incorrect treatment of the subject, and the employment of official reports is made to convey misleading conclusions.

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* *Report of Mr. W. N. Atkinson, H.M. Inspector of Mines, North Staffordshire, 1898*, pages 23 and 24.

† *Report upon the Morfa Colliery Explosion*, page 19.

‡ *Report for 1892*, page 6. § *Report for 1891*, page 6.

|| *Report for 1895*, page 12.

Again, Mr. Orsman charged the Thorncliffe and Tylorstown colliery explosions under Table I. (2) to tape-fuze, and omitted the facts that they were caused by shots charged with nitrate-of-ammonium explosives; also that Mr. F. N. Wardell and Mr. J. T. Robson, H.M. inspectors of mines, reported that there was no gas present to the safety-lamp test when the shots were lighted; and that in their opinion gas was concealed in the strata and liberated when the shots broke the ground open. At this moment the safety-fuze had expired in the detonator, and the products of ammonite and roburite at their exalted temperature remained the only means of igniting the gas that they had liberated, and with which they came into immediate contact.

After the same manner, Mr. Orsman charged the Hebburn colliery explosion to nitro-glycerine explosives, with a note "gelignite with roburite," but did not explain why he debited gelignite only with the disaster; nor did he mention the facts that the roburite of that period was very difficult to explode with a detonator,* or to the practice of using gelignite-primers to detonate roburite, which Mr. Orsman apparently had in his mind when, in June, 1892, he addressed the following words to the members:—"Further experiments proved that it was impossible to detonate or completely explode a cartridge of roburite except by means of a charge of nitro-glycerine or its compounds, or mercuric fulminate."† The gelignite therefore performed the function of detonator to the roburite at Hebburn colliery. Roburite being the bursting charge, was the principal source of heat and flame for igniting the gas.

The three explosions at Hebburn, Thorncliffe and Tylorstown collieries are recorded in official reports as due to shots charged with ammonite and roburite; but these explosives were omitted from Mr. Orsman's tables, and the disasters that they had caused were debited to other explosives.

Further examination did not appear necessary to show that the tables were misleading and incorrect when compared with the authorities to which the members were referred for verification. The examination had, however, provided the information for correcting Table II.; but the table was incomplete without the number of shots fired. It was obvious that as one shot may cause an explosion, it became the unit of risk; and equal numbers of units formed the fundamental basis for comparing the number of fatal shots of each explosive. Consequently the numbers of shots fired with each explosive must be added to Table II.

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* *Trans. Inst. M.E.*, vol. ii., page 32.

† *Ibid.*, vol. iii., page 576.

before a comparison between the fatal shots or explosions by each substance could be raised.

There were not any complete returns of the shots of each explosive fired in the 11 years ending 1897, but some records from the principal shot-firing districts had been published, and furnished the material for a practical estimate that could be added to Table II., which, after correction, was :—

TABLE II.—SUMMARY OF FATAL EXPLOSIONS OF FIRE-DAMP AND COAL-DUST DUE TO EXPLOSIVES DURING THE 11 YEARS 1887-1897, CORRECTED BY THE PUBLISHED REPORTS OF H.M. INSPECTORS OF MINES, WITH PROPORTIONS OF SHOTS ADDED.

Explosive or other Cause.	Percentage of Total Shots Fired.	Explosions.		Deaths.	
		Number.	Percentage of Total.	Number.	Percentage of Total.
Gunpowder	90	15	45·46	63	9·40
Nitrate of ammonium ...	10	4	12·12	67	10·00
Nitro-glycerine		4	12·12	342	51·05
Tonite		1	3·03	1	0·15
Safety-fuze	—	4	12·12	5	0·75
Unknown	—	2	6·06	88	13·13
Lights or lamps	—	2	6·06	74	11·04
Reversal of ventilation...	—	1	3·03	30	4·48
Totals ...	100·00	33	100·00	670	100·00

The corrected table indicated that the high explosives had in actual use proved more dangerous than gunpowder, inasmuch as when used in 10 per cent. of the shots, they caused 27 per cent. of the explosions and 61 per cent. of the deaths; while gunpowder in 90 per cent. of the shots caused only 45 per cent. of the explosions and 9 per cent. of the deaths.

It would probably be an excessive estimate to say that nitrate-of-ammonium explosives were used in 5 per cent. of the shots fired in the 11 years from 1887 to 1897, as not one of them was authorized for use in the first year, and only one in the second, the others following at intervals, their introduction with detonators being necessarily slow in opposition to the simple and economical gunpowder. The alleged superior safety of these explosives vanished before the fact that 5 per cent. of shots caused 12 per cent. of the explosions and 10 per cent. of the deaths. The prophecies of freedom from explosions held out as the inducement to substitute nitro-glycerine and nitrate-of-ammonium explosives for gunpowder, had entirely failed in experience; the new substances had in fact caused even more explosions relatively than the old blasting-powder, and Mr. Orsman's attempts to show the contrary were founded upon misrepresentations of the official reports as already disclosed.

The permitted gunpowders recently introduced were fundamentally superior to the old blasting-powder in the presence of fire-damp or coal-dust, and were prepared to be as far as possible incapable of igniting gas or dust in practical mining. Mr Orsman referred to the new gunpowders, saying, "All the new blasting-powders (with the exception of oxalate blasting-powder) contain the same, and no other ingredient than the older forms of blasting-powder . . . . and the solid products of combustion (*i.e.*, the fumes) will be even greater than the old blasting-powder." This statement was entirely wrong, and Mr. Orsman was evidently speaking from very imperfect and hearsay information as to the composition, manufacture and properties of these gunpowders. He (Mr. Stuart) had used considerable quantities of the permitted gunpowders in coal-mines, and found the smoke was less than one-half that yielded by ordinary blasting-powder for the same work; and certainly not more than the smoke produced by equal weights of roburite and carbonite. The compositions of the new powders and the incorporation were so altered as to produce a fundamental change in their chemical actions, which was exhibited in the fact that the products proved incapable of igniting the inflammable gaseous mixture at Woolwich, while the products of ordinary blasting-powder fired in identical conditions did ignite this gas. The opposing behaviour of the two classes of gunpowder in the inflammable gas, one igniting the gas, the other incapable of doing so, demonstrated a fundamental difference between them, which submerged Mr. Orsman's theories, and he was evidently quite at sea on the subject.

Mr. Orsman was also mistaken in describing the elephant cartridge as having "a plug at one end containing oxalate of ammonia . . . which would probably be useless if the cartridge were placed in the hole wrong end about." There was no plug in the cartridge. The oxalate of ammonium was a granular powder exposing a maximum surface. A cartridge containing 9 ounces of elephant gunpowder and 4½ ounces of "cooler" had been tested at Woolwich by firing it wrong end about, *i.e.*, the cooler at the inside end of the cannon-bore, and the gunpowder next to the inflammable gas. The cartridge, when fired in this position, proved as incapable of igniting the gas as when fired in the proper way; and the fact afforded demonstration that the cartridge was equally safe in this severe test. He (Mr. Stuart) had found by using the cartridge in coal-mines that it did not yield fumes; but in fast ends and narrow faces beyond the circulating current, traces of ammonia-gas were sometimes detected, which were wellknown to be harmless and altogether different from the injurious nitro-benzene fumes of nitrate-of-ammonium explosives.

The permitted gunpowders were now undergoing the test of experience in the various conditions of coal-mining, and could not be condemned unless and until experience proved that they did not possess the high degree of safety of which they had afforded evidence. Mr. Orsman had attempted to condemn the powders without trial, and in fact before their properties were known, which was obviously premature, and prejudicial to the best interests of coal-mining, and the labour and research constantly given to promote its safety. The permitted gunpowders were the outcome of immense labour and research, and supplied the coal-mining industry with explosives possessing the unequalled blasting properties of the old gunpowder, with double its power, thereby reducing the charge 50 per cent. and to equal weights of the permitted nitrate-of-ammonium and nitro-glycerine explosives, save gelignite. The new powders were also protected in spark-and-friction-proof cartridge-cases, securing them from accidental ignition in conveyance or charging —the source of more than 50 per cent. of the accidents with gunpowder. These gunpowders had been tested by a Government Committee, comprising H.M. inspectors of explosives and inspectors of mines, who fired them in charges of 6 to 9 ounces (equal to 12 and 18 ounces of ordinary blasting-powder) in blown-out shots into a highly inflammable gaseous mixture, but they would not ignite the gas. These severe tests, apart from the exceptionally superior nature of the gunpowders, established a reasonable claim for their adoption in fiery and dusty mines, for which they had been certified by the Government Committee, and upon the same tests as the committee certified all the other permitted explosives: excepting the fact: - The test-charges of gunpowder were from 2 to 4 times heavier than the test-charges of nitrate-of-ammonia and nitro-glycerine explosives, consequently the gunpowders being of equal blasting-power possessed the superior standard of safety due to the severer test-charges.

THE INSTITUTION OF MINING ENGINEERS.

GENERAL MEETING,

Held in the Rooms of the Geological Society, Burlington House, London, May 26th, 1899.

Mr. J. A. LONGDEN, President, in the Chair.

Mr. Douglas S.-S. Steuart read the following paper on "The Mineral Wealth of Zoutpansberg: The Murchison Range Gold-Belt":—

THE MINERAL WEALTH OF ZOUTPANSBERG: THE MURCHISON RANGE GOLD-BELT.

By DOUGLAS S.-S. STEUART, B.Sc., Assoc. M. Inst. M.E., Assoc. Inst. M.M., F.G.S., F.C.S., etc.

I.—Introduction.

Between 10 and 11 years ago, at the time of the boom in the Transvaal, a rush took place to the Zoutpansberg gold-fields, and hundreds of claims were pegged indiscriminately over large areas, from Leydsdorp on the west, to Witkoppies on the east, at that time distant over 200 miles from the nearest railway. Numerous companies were floated and a few mines opened up to a limited extent, but they, with one exception, were shortly afterwards closed, for reasons relating more closely to the direction and financial management of the companies than to the values of the properties. In June, 1898, the writer was induced by a prospector and hunter, to exchange the dust and bustle of the "Golden City," for a few days' hunting and prospecting on the Murchison Range. Rifle and bandoleer were soon laid aside for the pick and pan, the days lengthened into weeks, and the first results of prospecting on Blue Jacket Hill (about 7 miles east of Leydsdorp) were so satisfactory, that it was decided to make an expedition down the Range to Witkoppies, for the purpose of further examining the 30 intervening miles of auriferous formation, in order to obtain a general idea, so far as possible, of the economic value of this gold-belt. After making a lengthy and comprehensive examination of the district, the author is of opinion that all indications point to the existence of extensive gold-bearing reefs, of both high and low grade, in the strata of the Murchison Range, and that the economic conditions prevailing to-day are such as will admit of these reefs being worked at a considerable profit. In view of the great extent of this gold-belt, comprizing (according to the Transvaal State Mining Engineer) 70 miles along the strike of the reefs, with an average width of 4 miles, the question of its value is one, the importance of which, from a mining point of view, can hardly be over-estimated.

II.—GENERAL DESCRIPTION OF THE ZOUTPANSBERG DISTRICT.

(1) *Topography and Extent.*—The district of Zoutpansberg (Salt-pan Mountain) forms the northern portion of the Transvaal and comprizes about 25,000 square miles, of which the proclaimed gold-fields cover an area of 3,500 square miles. There are two main divisions, the Western or High Veldt, and the Eastern or Low Country : the principal gold-fields occurring in the latter. These portions are intersected by two great mountain-ranges, the Zoutpansberg running from south-west to north-east, and the Drakensberg from south to north. Only two streams of importance, the Zand and Hout rivers, flowing approximately from south to north, drain the High Veldt, whereas the Low Country possesses an extensive drainage system, formed by the Olifants, the Selatie, the Great Letaba, the Middle Letaba, the Klein Letaba and the Levubo or Pafuri rivers, with their numerous tributaries. The three Letaba rivers uniting into one great river, join the Olifants river about 60 miles east of Leydsdorp in latitude 24 degrees south and longitude 31 degrees 52 minutes east of Greenwich. These rivers are fed mainly from the extensive catchment area of the Drakensberg, which rises abruptly above the plains to an average height of about 2,500 feet ; the Volksberg, probably the highest mountain in the whole district, rising to about 7,000 feet above sea-level (Sketch Map, Plate XII.).

(2) *Stratigraphy.*—As the richest gold-bearing zones in the Transvaal are intimately related to the stratigraphy of the country, a true understanding of this is highly important. In the case of the African Primary formations, considerable difficulty is found in correlating the several series with the recognized geological horizons, mainly on account

of the various forms under which apparently the same formation occurs in different parts of the country. The following table represents the stratigraphical sequence of the Primary series of the Transvaal, based on the most recent information :—

Transvaal.	Europe.
7.—Karoo Coal-bearing Sandstone.	Upper Carboniferous.
Slight unconformity.	
6.—Pretoria-Magaliesberg Quartzites.	Middle Carboniferous.
Conformity.	
5.—Dolomitic Limestone.	Lower Carboniferous.
Conformity.	
4.—Black Reef, Drakensberg and Table Mountain Sandstone.	Lower Devonian.
Unconformity.	
3.—Witwatersrand Auriferous Conglomerates.	?
Doubtful unconformity.	
2.—Barberton Series, Hospital-Hill Slates and Swazi-Lydenburg Schists.	Silurian or Cambrian.
Unconformity.	
1.—Namaqualand, Letaba and Murchison Range Schists, Quartzites, Gneisses and Granites.	Pre-Cambrian.

III.—General Geology.

As will be seen from the map (Fig. 1, Plate IX.), the rocks exposed along the section *A–B* (Fig. 3, Plate X.) consist essentially of the Drakensberg Sandstone, which lies almost horizontally upon the upturned edges of the Letaba-Murchison-Range Schists. Intrusive dykes are not uncommon, and especially noteworthy is an extensive diabase outcrop between Haenartzburg and the Great Letaba river, traversing the valley of the latter, apparently in the form of a dyke and seemingly representing a line of fault. It is interesting to observe that the vegetation growing along the lines of diabase-dykes is distinctly richer than where less fertile soil-producing rocks occur.

South-west of Pietersburg, the Dolomitic Limestone, Magaliesberg Quartzites, and Coal-bearing Sandstones occur.

Dealing in ascending order with such of the series as bear upon the geology of the district under consideration, there are :—

(1) *The Letaba and Murchison Range Schists.*—The rocks of this series are held by some geologists to be identical with the Barberton formation, others again consider them to be pre-Cambrian, and the results of the author's examination favour the latter view. These rocks, typically developed in the Murchison Range, are, as a whole, highly crystalline and schistose, showing abundant evidence of regional as well as contact metamorphism, and granites and gneisses occur over large areas and exhibit the peculiar foliation and banding of the constituent minerals characteristic of the crystalline schists. Layers of amphibolite, chlorite, sericite, hornblende, actinolite, tremolite, etc., are intercalated with veins of quartz, and interbedded with schistose and micaceous quartzites, frequently wedged in between eruptive dykes, sometimes of a basic, and sometimes of an acid character. The existence of orbicular limestone at Klein Letaba is worthy of note. The whole series of these metamorphic schists and quartzites is tilted almost vertically, having, doubtless, been thrust into this position by a great upheaval of the basement rocks which are principally granitic, the schists and granites being broken through by intrusive dolorites, diabases and diorites, in the form of dykes, bosses and sheets, and containing numerous richly auriferous quartz-veins. The whole has undergone, subsequently, an enormous amount of denudation, the auriferous schists having been denuded away from the greater part of the area they once covered, and they only occur in the localities shown in the map (Fig. 1, Plate IX..) the Olifants river, Murchison Range, Molodotsi and Klein Letaba, etc.

(2) *Barberton Series, Hospital-Hill Slates and Swazi-Lydenburg Schists.*—This series is greatly developed in the Barberton district, where the formation is abundantly auriferous, and several mines are working at a satisfactory profit. It does not apparently occur in the Zoutpansberg district, or else has been entirely denuded.

(3) *Witwatersrand Series.*—This series was for a long time thought to belong to the Black Reef formation, but the latest evidence as to conformability suggests that this auriferous series is probably the representative of a formation which is older than the overlying Black Reef, but younger than the underlying Hospital-Hill Series. Before discussing the possibility of the existence in the district of the equivalents of the Witwatersrand formation, it will be necessary to deal with the overlying series.

(4) *Drakensberg, Black Reef and Table Mountain Sandstone.*—This formation consists principally of sandstone, quartzite, and conglomerate beds, and is typically developed, as the name implies, in Table Mountain at Cape Town; in the Drakensberg, as the Drakensberg Sandstone; in the eastern portion of the Transvaal, as the Kantoor Sandstone; and in the Southern Transvaal as the Black Reef Series, so called from the occurrence therein of one or more auriferous conglomerate beds, named the Black Reef. The main argument in favour of the distinction of the Witwatersrand Series from the Table Mountain Sandstone is based on the fact that the latter formation has never been found other than unconformable to the underlying Barberton Series (Hospital-Hill Slates, and Swazi-Lydenburg Schists), whereas the Witwatersrand strata are in all probability conformable thereto.

This argument will not, however, apply to the great sandstone-and-conglomerate series of the Drakensberg Range (between the High Veldt and Low Country of the Zoutpansberg district): if the underlying schists are pre-Cambrian and therefore lower than the Barberton formation, the Witwatersrand Series, if present, would necessarily overly them unconformably, as do the conglomerates at the base of the Drakensberg. As the dolomite is conformable to the Black Reef Series, and the latter unconformable to the Witwatersrand formation, the occurrence of dolomite overlying the Drakensberg Series conformably would identify the whole series with that of the Black Reef, unless, of course, an unconformity existed between the upper and lower portions of the Drakensberg Series, in which case the latter might be safely correlated with the Witwatersrand formation. So far, the writer has been unable to obtain evidence on either of these points. In any case, it is obvious that enormous denudation of extensive and highly auriferous formations (probably all of the Barberton and most of the Letaba Murchison Series) took place prior to the deposition of the Drakensberg Sandstone, and it is therefore reasonable to look for the occurrence of gold in the overlying fragmentary series of the Drakensberg. In support of this opinion, it is satisfactory to record the occurrence of auriferous banket at the base of the Drakensberg Series, close to the town of Haenartsburg. Samples have yielded from 5 to 15 dwts. per ton, and as there is available water-power close at hand at the Great Letaba river, and native labour is very cheap, the possibilities of profit from working this extensive series are such as warrant the most careful and systematic prospecting.

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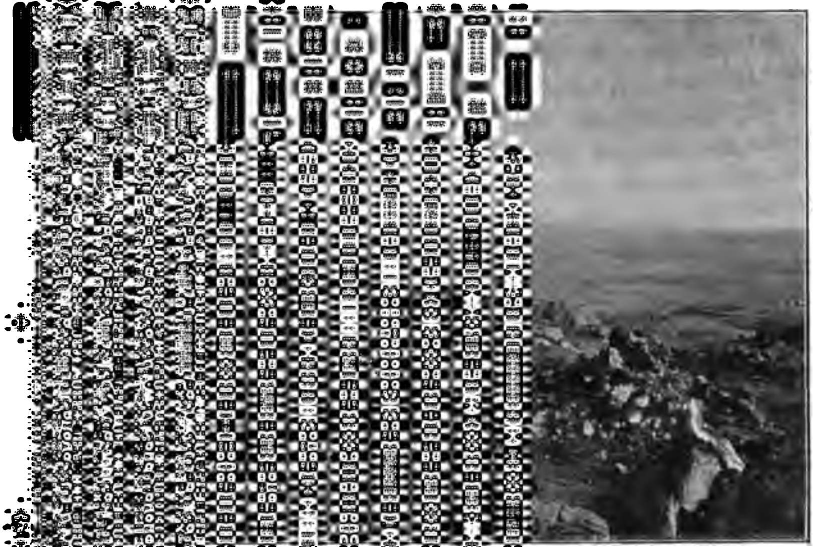

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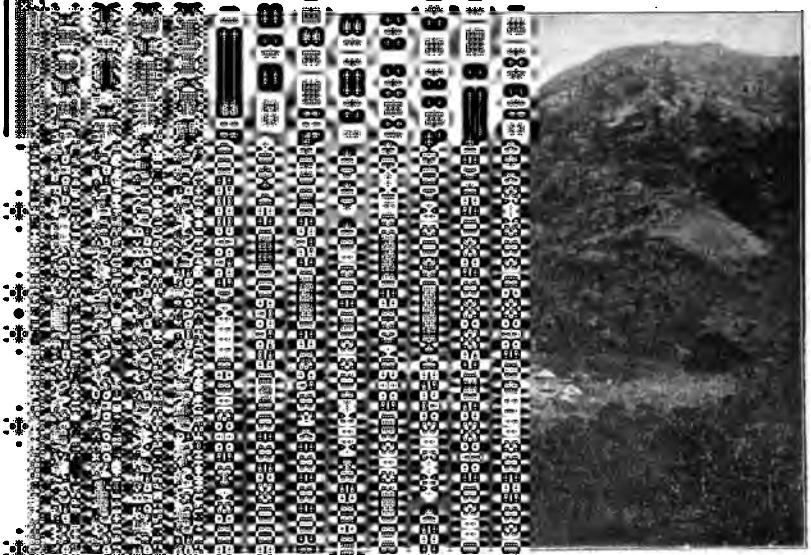

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DSTONE.

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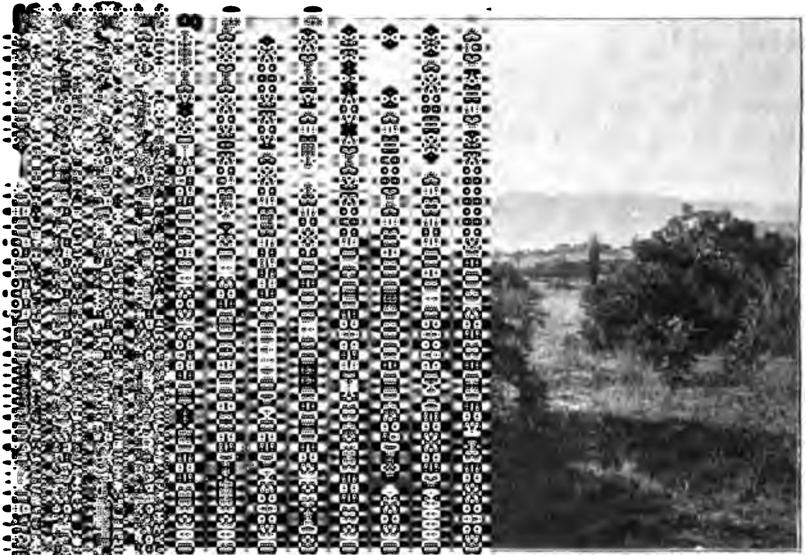

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Low Country, at Leydsdorp,

the chief town of the Murchison Range, the summer heat is much greater, but is at the same time very dry, the town being 2,100 feet above sea-level. The average maximum temperature for the summer months (December to March), during the day-time, ranges from 100° to 105° Fahr., but hot nights, which are so trying to Europeans, are practically unknown, the average minimum temperature for the above period ranging from 60° to 65° Fahr. In the winter months, the climate cannot be surpassed. Deaths from fever are very rare, and such cases as have occurred up to the present time, have been amongst those living more or less carelessly, and there are many who have resided for several years on the range without ever having suffered from the fever, which in this locality is of a climateric intermittent nature, not strictly malarial, and can be easily guarded against by taking the proper precautions.

VI.—AGRICULTURE.

The soil of the Low Country is remarkably fertile, and with very little trouble beyond watering, almost every kind of fruit can be readily grown, including oranges, lemons, melons, pine-apples, bananas, peaches, tomatoes, mealies, coffee, tobacco, etc., and this, in a tropical country, is an important safeguard against illhealth. It may be mentioned that the country at the foot of the Drakensberg, along the Great Letaba river, offers splendid facilities for agriculture. A small area of ground put under cultivation some years ago yielded, last season, 7 tons of coffee of the finest quality.

VII.—THE MURCHISON RANGE GOLD-BELT.

(*a*) *Location and Extent.*—The Murchison Range (Fig. 1, Plate IX.) forms the watershed between the Selatie and Great Letaba rivers. The total distance, from the western extremity down to the Witkoppies, is about 50 miles, but the auriferous formation is reported to cross the Great Letaba river and extend for a further distance of 25 miles, maintaining its east-north-easterly course.

(*b*) *Topography.*—The map (Fig. 1, Plate IX.) is compiled from the author's own observations, with the assistance of Messrs. William Lawrence and H. Standen, who have spent many years on the Murchison Range, and whom the author takes this opportunity of thanking, together with Messrs. Brown and Madross, for valuable services rendered him in the prospecting and exploration of the range. This sketch-map is the only one of its kind including the whole of the range, Only the main topographical features have been included, and these, it is hoped, will be found approximately correct, but owing to the great extent of the area and smallness of the scale, all detail has of necessity been omitted.

The Murchison Range may be described as a double chain of hills, partly continuous and partly detached, running, for the most part, parallel one to another, and in the same direction as the strike of the strata, and separated by a valley varying from 2 to 3 miles in width. The western extremity of the auriferous formation crops out from under the almost horizontal beds of Drakensberg Sandstone, south of the Letsitele river, below Agatha, where it forms the Thabine gold-fields; the Murchison Range, proper, commencing on the north-western boundary-line of the Harmony block (Fig. 2, Plate IX.). From this point, the northern or Antimony line extends through the Murchison Crown, Gravelotte, Free State, Kasteel Koppies, etc., in an east-north-easterly direction to beyond Witkoppies, finally dying away in the Letaba flats. The southern, or Spitzkop line, which may be said to commence on the Potsdam farm, extends in an approximately parallel direction, through Leydsdorp, Spitzkop, Blue Jacket Hill, etc., to La France, whence it follows the bend of the Selatie river, finally terminating close to the junction of the latter with the Melatie river; this rises in the Rooiwater, about 6 miles north of Leydsdorp and the Antimony line, through which it crosses into the valley, about 12 miles to the east, flowing along between the two chains of hills until it joins the Selatie river, south-east of La France, but in the dry season only the lagoons contain water. The Selatie river, which always contains a good supply of water, runs from 2 to 4 miles south of the Spitzkop chain, at the eastern extremity of which it takes a sharp turn to the south and flows into the Olifants river. The Great Letaba, one of the biggest rivers in the Low Country, runs about 14 miles north of the Murchison Range, joining the Olifants river far to the east.

(*c*) *Geology.*—The general geological structure of the auriferous strata having been already described, it is only needful to refer to such features as bear more especially upon the mineral value of the gold-belt.

The strike of the formation runs about east-north-east, and approximately parallel to the run of the hills, the average inclination varying so little from the vertical, throughout, that no opportunity was found of calculating the thickness of the formation, which, judging from the declining sections of the country, might be anything from 1,000 to

3,000 feet. The invariably almost vertical position of the schists upon the granite-rocks is remarkable, and is well shown in the section across the range, through the Lion Kopje (Fig. 4, Plate X.). It is difficult to account for this vertical position of the strata, other than by supposing, that the schists were originally intruded into by immense eruptions of granite, probably along lines parallel to their strike, the centres of upheaval being midway between the present auriferous belts. The dynamic metamorphism would be so great, as to destroy all synclinal structure at or near the surface, and the enormous pressure in these regions has been such, as to convert soft clay-slates into intensely hard amphibolites, eruptive rocks into hard foliated gneisses, and sandstones into schistose quartzites so hard as to be almost imperishable, and with these the tops of most of the kopjes are crowned. The anticlines would, on the other hand, represent areas of extreme tension, even in those localities where the intrusive mass did not burst through and shatter the overlying formation, as must have occurred in many cases. It is evident that, at the start, the agents of denudation would work most effectively along the lines of anticlinal tension and rupture, at any rate, until the overlying schists had been removed from the eruptive granite and syenites. According to the above theory, they have not only done this, but have worn down, what were originally the anticlinal areas of elevation, to a depth of at least 1,000 feet below the areas of synclinal compression. The author's observations in this direction are altogether in favour of the above view.

In the height of summer, the surface-rocks in the district are often heated to a temperature that cannot be far off 170° Fahr. during the day, while during the night, the temperature will fall to 60° Fahr., giving a range of at least 100° Fahr. in a few hours. The highest temperature recorded on the range during the day was 134° Fahr., the minimum temperature for the ensuing night being 60° Fahr. Last winter, which was an exceptionally severe one in South Africa (a temperature of 15° Fahr. having been recorded on the Witwatersrand), the temperature on the Murchison Range fell so low, for a few nights, as to convert a cup of water into a block of ice. These alternations of temperature have acted in a very curious way upon many of the eruptive rocks, syenites, porphyrites, etc., causing the shelling off of thin concave layers from the surface, and giving the rocks a rounded and pseudo-glaciated appearance. Some of these fragments, which are very abundant, measure 6 by 4 inches, and are from ⅛ to ½ inch in thickness. In some cases, flat granitic slabs would ring quite hollow under the hammer, and on being struck with sufficient force, a portion of the upper crust would come away, exposing a space of about ⅛ inch between the two layers, containing a soft white powder, in all probability kaolin, formed by the decomposition of the felspar. It is obvious that under such circumstances, disintegration must proceed with great rapidity, and this, together with the annual heavy rains and torrential floods, must cause exceptionally rapid denudation. A glance at the general configuration of the country as depicted in the map (Fig. 1, Plate IX.) will show how more than probable it is, that, at one time, the Devonian strata of the Drakensberg extended many miles to the eastward of their present position. There is no evidence to show the origin of the eastern and western lines of rupture, unless they represent lateral fissures, resulting from the upheaval of the great Drakensberg chain of mountains crossing them at right angles, to the west.

(*d*) *Igneous Eruptive Rocks.*—Numerous varieties of eruptive rocks occur both on the range and in the granite-valley, as shown by the map (Fig. 2, Plate IX.) and sections (Figs. 3, 4 and 5, Plate IX.; and Figs. 6 and 7, Plate X.). They may be divided provisionally into two groups:—

(1) Older dioritic and basaltic dykes, mostly the former, which can be traced continuously for a considerable distance along the Murchison Range, their strike being approximately parallel to that of the schists, with the dip of which they coincide. This is shown in Fig. 5 (Plate X.), which represents a section across the Blue Jacket Hill, cutting the Manipa Bar, a big diorite-dyke, which runs north of the Spitzkop line, for a distance of at least 15 miles, also shown in Fig. 5, where a large porphyritic basalt runs for a considerable distance parallel with, and in close proximity to the neighbouring reefs. In another instance, as shown in Fig. 6 (Plate XI.), being a section across La France mine), a basaltic trap is found to follow very closely the turnings of the strata and the reef. It is evident, therefore, that the eruption of these rocks was practically contemporaneous with the formation of the numerous fissures and lines of fracture traversing the strata, which form the main depositories of the mineral lodes.

(2) A younger series of trap-rocks, mostly of a less basic character and smaller dimensions, which are intruded into the schists, traversing them in varying directions and frequently intersecting the reefs, as shown in the section (Fig. 5, Plate X.), across the Gravelotte Hill, where one of these dykes, running approximately north and south, has faulted the Black Reef about 15 feet out of its original coures.

(3) A variable and generally more acid series of trap rocks, intrusive principally into the granites, gneisses and syenites of the valleys, which although entirely disassociated from the auriferous formation, are intimately related to the occurrence of other mineral deposits. This series undoubtedly offers a very interesting field for petrological research.

The results of a careful investigation all point to the fact that the older dioritic and basaltic dykes exert a very important influence upon the auriferous nature and permanency of the associated reefs, and the following observations as to their lithological character and mode of occurrence in the district are therefore noteworthy. In the adit-drive in the Blue Jacket Hill, the large dioritic dyke is cut through, exposing a section of about 35 feet (Fig. 9, Plate XI.). The appearance of the rock is characteristic, atmospheric erosion leaving hard, central, spherical nodules of bluish-green diorite, showing concentric layers of semi-decomposed material gradually passing into a soft, loamy, greenish-brown mass. Although highly refractory in its normal state, this rock undergoes chemical decomposition (and therefore disintegrates) much more rapidly than the metamorphic schists and quartzites through which it passes. Consequently, long ridges are formed, of what look like water-worn boulders, but which are nothing more than the undecomposed cores resulting from the concentric and spheroidal weathering of the diorite, which apparently disintegrates more rapidly below the surface, where it doubtless gets washed away from under the more imperishable cores, these latter settling down and accumulating on the surface, as is well shown in the section (Fig. 9, Plate XI.). Beneath these lines of boulders, the dykes are often disintegrated to considerable depths, forming, in the case of the diorites, a compact argillaceous mass, represented in the basalts by a loose friable substance, doubtless due to the smaller percentage of clay-producing minerals contained in the latter. As before mentioned, the strike of these dykes can often be detected, in the absence of other surface-indications, by the local change in the vegetation above them, due to the exceptionally fertile nature of their soils.

(*e*) *Reefs.—Structural Character.*—The auriferous ore-deposits of the Murchison Range may be divided structurally into two main divisions:—

(1) Fissure-veins or Bedded-veins. The latter only differ from the former, in that their course is parallel to the bedding-planes of the strata between which they occur. Owing to the previously described

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Plate XI.). These veins
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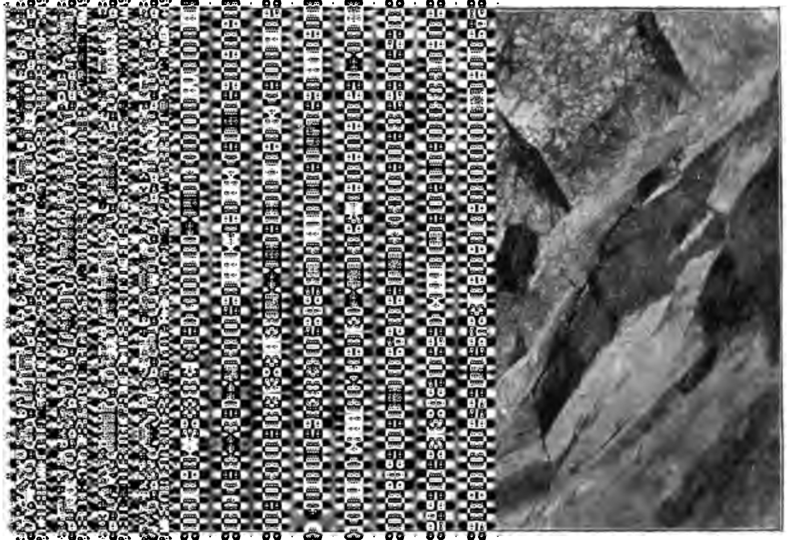

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foot-wall or hanging-wall not being uncommon. The reefs are consequently more or less irregular and lenticular, and range from 2 to 24 feet in width, but from 4 to 5 feet may be taken as a fair average.

(*f*) *Faulting, Dislocation, etc.*—The auriferous formation is most broken at its western extremity close to the Drakensberg, but the disturbance is less marked toward the east, and from the neighbourhood of Leydsdorp right up to the Witkoppies the strata are fairly regular. The faulting along the rest of the gold-belt is not very great, and is represented by intrusions of trap and dykes, together with a few younger non-auriferous reefs. The main lines of fracture existing in the range are specially important on account of their number, permanence, uniformity and extent; they are, for the most part, either filled with igneous intrusions or siliceous and ferruginous vein-stuffs, in many instances richly mineralized. They present the common characteristics of compression-fractures, slickensides, striations, and selvages abounding, while fragmentary particles and parallel sheets of the country-rock frequently occur, together with minor fissures at right angles to the main lines of fracture, which latter, as a rule, only exhibit faulting and displacements of any importance in those regions where the presence of sudden breaks in the continuity of the range betokens the occurrence of more extensive earth-movements. The younger lines of fracture which traverse the formation (frequently intersecting and dislocating the main lines to a small extent) are mostly represented by intrusives of a more acid character, or else contain non-metalliferous quartz.

(*g*) *Mineralogical and Lithological Character of Reefs.*—Mineralogically, the reefs of the Murchison Range may be divided, provisionally, into three groups: (1) Those in which antimony is the most prominent mineral; (2) those in which the principal constituents are ferruginous compounds; and (3) those composed mainly of quartz.

(1) *Antimony Group of Reefs.*—The reefs of this series, which traverse the northern belt of the range, are characterized by an abundance of antimony mixed with the quartz, principally in the form of stibnite, the oxide occurring also, from decomposition of the sulphide. The main lode has been traced intermittently from Gravelotte Hill to Witkoppies, a distance of about 30 miles, the width at the surface averaging about 4 feet, although it is far from uniform, varying from 1 to 10 feet. A vein of pure stibnite with oxide traverses the

lode, of which it sometimes forms 75 per cent., the former containing 71·40 per cent. of antimony and 28·60 per cent. of sulphur, and the latter giving 93·60 per cent. of oxide, with 6·10 per cent. of silicates. The value of the gold-content is very variable, rich chutes occurring at intervals along the reef. The gold exists not only in the quartz and oxide, but also in the mass of the stibnite, where it is frequently to be seen with the naked eye. Assays of samples showing no visible gold, yielded 5 ounces 18 dwts. 18 grains per ton, and other samples with visible gold gave 18 ounces 12 dwts. 12 grains of gold per ton. On either side, and within a few feet of the main lode, with which they are no doubt genetically connected, are two smaller reefs cropping out at intervals along the range. They are highly mineralized, containing stringers of auriferous quartz associated with iron, antimony, traces of copper, and occasionally showing visible gold.

(2) *Ferruginous Group of Reefs.*—The reefs of this series occur along both the Spitzkop and Antimony lines, and are notable for the large amount of iron which they contain. Above the zone of oxidation, the reef-matter often contains from 30 to 45 per cent. of ferric oxide, with about 50 per cent. of silica and some alumina, and consists of a soft, friable, highly coloured matrix, yellow, brown, red or black, including lenticular bands and irregular fragments of dark and light coloured sugary-to-glassy quartz, of which stringers and laminæ frequently occur parallel to the stratification of the country-rock, the lodes in some cases exhibiting a banded structure. The presence of so much hydrated ferric oxide has earned for these lodes the title of Black or Burnt Reefs. Coarse and fine gold is frequently met with, both in the matrix and in the quartz, in small nuggets and leaf-like plates, some of the stringers being extremely rich. Samples have yielded from 2 to 3 ounces of gold per ton, but as a whole, the grade averages all round from 12½ to 15 dwts. per ton: an important characteristic of these Black Reefs being the evenness with which the gold is distributed throughout their substance. At a depth of about 200 feet, the matrix becomes hard and compact, dark greenish in colour, and containing abundant pyrites, with traces of antimony and copper. The average width of the lodes is about 5 feet, and they have been traced intermittently nearly the whole length of the Murchison Range.

There are three main lines, one running along the northern chain of hills, a short distance south of the antimony-lode, which it follows from west of the Gravelotte to as far as the Witkoppies.

A second line, cropping out a few miles east of Leydsdorp, runs along the southern slope of the Spitzkop chain as far as Blue Jacket Hill, where it makes a sharp turn over the mountain, and for the rest of its course keeps on the north side of this range. An auriferous reef, with which it is probably identical, has been located on the Melatie river between La France and Kasteel Kopjes.

A third line of reef has been traced at some little distance south of the Spitzkop hills, running through the Blue Jacket Hill, and thence for a considerable distance both to the east and west, representing very probably the lode opened up at La France. In the proximity of these three main lines several smaller ferruginous reefs occur, but these, at the surface, carry only traces of gold up to 1 dwt. per ton.

(3) *Quartz Group of Reefs.*—To this category, comprising all lodes in which quartz (silica) is the most prominent and important mineral, belong a considerable number of the reefs on the Murchison Range: these are distinguished from the preceding groups by the comparative scarcity of base metal or refractory minerals, and by the essentially free-milling nature of their gold-content. The quartz exhibits great variety, both in texture and colour, being massive, laminated, granular, crypto-crystalline or glassy and compact, at times passing insensibly into schistose quartzite or intercalated with sheetings of the country-rock; it is colourless or of various shades of grey, green, red or brown, and occasionally of such transparency that the gold can be seen through ½ inch of the matrix. The reefs follow approximately the planes of stratification, frequently running parallel with, and in close proximity to, intrusive dykes, and crop out for long distances. Sublenticular and irregular, their width varies considerably (from 1 to 8 feet), the probable average being about 3 feet. The gold-contents are equally varied, in a few localities being of a rich and patchy nature, but as a rule occurring in rich chutes of considerable extent, alternating with ore of lower grade. Gold is commonest in the drusy cavities of the quartz in which decomposition has often replaced the original pyritic crystals by oxide of iron; it also occurs in fine grains scattered through the harder and more glassy quartz, plastered in crystalline aggregates on the foot- or hanging-walls, in the form of delicate films and laminæ, coating the surface of intercalated masses of schist, or in coarse fibrous and arborescent veins of extraordinary richness, containing nuggety fragments of gold, weighing occasionally as much as ¼ ounce.

The lodes of this group are numerous, and those of importance may be divided provisionally into three main lines.

The first of these, probably starting at the north-western extremity of the range, comprises apparently three different reefs which run eastward along the northern chain of hills, until, approaching the vicinity of the Gravelotte Hill, the first or northernmost line becomes identified with the vein of stibnite, which also appears to a less extent in the second; while the third, or southernmost reef, crops out at rare intervals to the east, striking south of Selkirk, and on past Kasteel Kopjes, where apparently the two northern reefs, free from antimony, form considerable outcrops, striking eastward to the Witkoppies, at which point antimony again makes its appearance. The above reefs, where (east of Gravelotte Hill) they are free from antimony, are known as the Melatie Series.

The second line of lodes may be said to commence in the much disturbed locality of Sutherland, on Potsdam Farm, the eastern extremity of the Spitzkop chain, along which it continues to the western limit beyond La France. From two to four distinct main reefs are traceable at intervals along the line of hills, occasionally on the northern side, sometimes along the top, but striking mostly along the southern slope, and frequently following lines of igneous intrusions. They attain their maximum development in the neighbourhood of Spitzkop and Blue Jacket Hill, where the formation is less disturbed than in the vicinity of Leydsdorp, and at present constitute the richest reefs located on the Murchison Range.

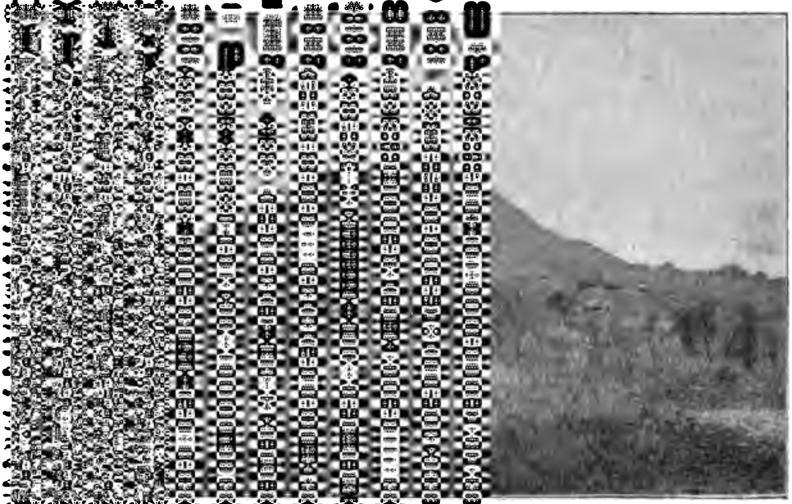
The third line of lodes is located on the flats, a considerable distance south of the Spitzkop chain. It is represented by from two to three lines of reef, yielding in a few places up to 1 ounce of gold per ton, but they have not been prospected to any great extent.

In order to convey a correct idea of the economic value of the Murchison gold-belt, the following description is given of the principal areas on the two ranges that have yielded, on prospecting, results of importance. The total length dealt with comprises about 50 miles, from the Harmony block on the west to the Caledonia on the east, the position of most of the principal localities being indicated approximately on the maps and by sections (Figs. 1 to 7, Plates IX., X. and XI.).

VIII.—BLUE JACKET HILL.

The reefs in this locality have been extensively prospected by the author, over an area measuring approximately 4½ miles along the strike of the lodes by about ⅓ mile across. The plan (Plate XII.) shows the relative positions of the various reefs in regard to the line of hills, of the sition of the Selatic river, ment accomplished is also more especially with the

the Blue Jacket Hill rises trending in an east-north- he Spitzkop. The latter, a itself, forms the most con- uptly and precipitously to a nd trending slightly north- for several miles without a



NORTH-EASTWARD, THE SITES THE DUMPS.

enclosing rocks of this line talcose and hornblendic es, highly metamorphosed, the Blue Jacket Hill, the , other than the north-to- Spitzkop. Taken in order traverse this hill, as shown Plate X.; and Fig. 9, Plate

e second main line of the n in the plan (Plate XII.),

tre of Blue Jacket Block
at the south-western end,
k on the reef to a depth
an average yield over the
wts. 12 grains of gold per
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ity throughout, the lode
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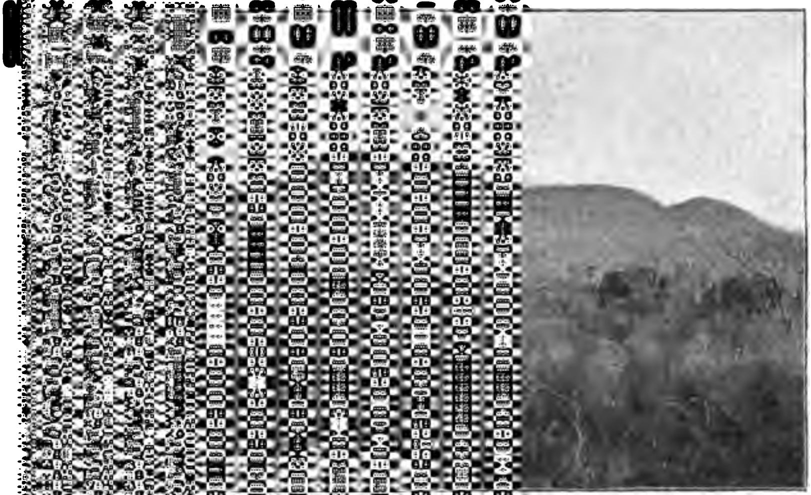
two shafts of 40 and 13
respectively 14 dwts. and



KING SOUTH-EASTWARD.

hird main line of the Black
o. 1 reef, which it resembles
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ins of gold per ton, over a
crops out at two points in
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n 3 to 4 dwts. of gold per

ngs to the second line of
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ck of claims, and has been
d in the map (Plate XII.).

[illegible] gold-bearing right across, [illegible] feet shaft, 80 ounces to [illegible] the 10 feet shaft, 4 ounces, [illegible] igh as 150 ounces per ton.

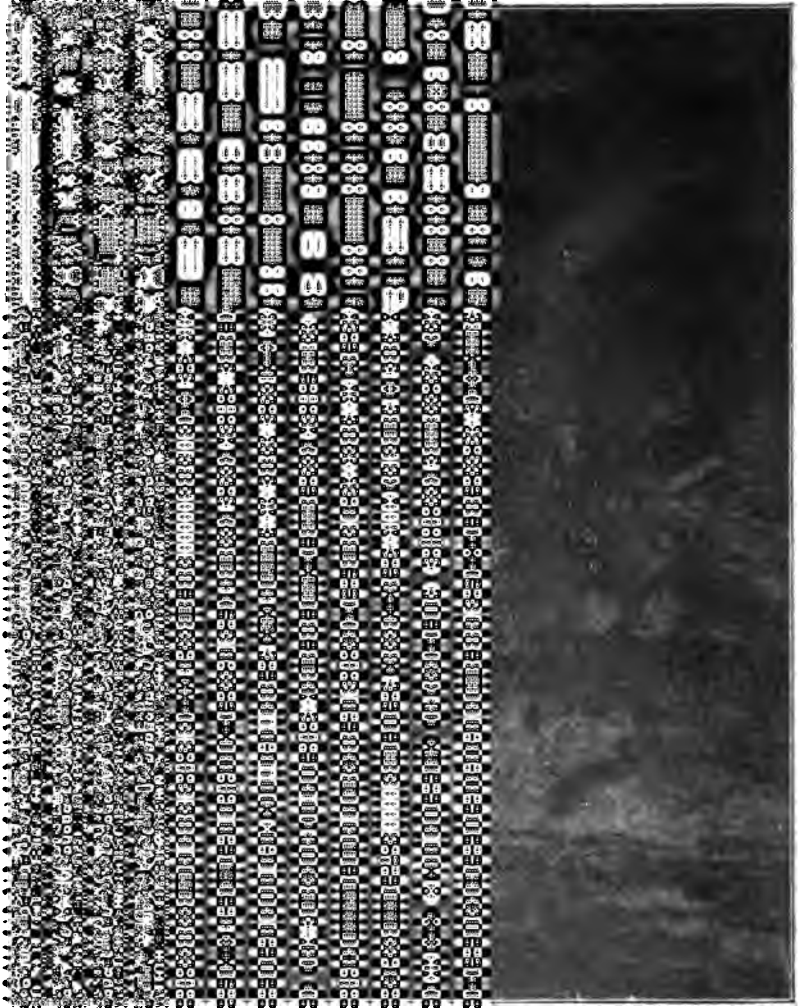

FIG. 19.—VIEW OF REEF IN 55 FEET SHAFT, BLUE JACKET HILL BLOCK B CLAIMS.

[illegible], close to the south-western [illegible] to a vertical depth of 55 feet. [illegible] feet level, rapidly increasing [illegible] vein of coarse nuggety gold [illegible] arent quartz, in some places attaining 1 inch in width, in others, branching in arborescent ramifications, sheetings of the schistose wall being frequently found encrusted with the precious metal, the extraordinary richness of which may be judged from the fact, that 2 cwts. taken over the 3 feet of reef yielded 50 ounces of gold, equivalent to 500 ounces per ton. This chute or vein of gold is remarkable for its continuity, only exhibiting interruptions in a few interesting cases where the reef has been dislocated approximately at right angles to the dip and subsequent to the introduction and solidification of the gold, which is torn and sheared along these planes in a most conclusive manner (Fig. 19). Its present value, in this shaft, may be taken at from 25 ounces and upwards, while in the next 50 feet shaft sunk on the reef and situated about 200 feet to the north-east, stone carrying 12 ounces to the ton has been obtained, the outcrop of the reef being easily followed up the steep side of the hill for another 600 feet. There, in a small 12 feet shaft, the quartz still shows visible gold, and samples have been obtained yielding 3½ ounces to the ton. From this point, the reef strikes north-eastward, and several outcrops have been located at intervals, over a distance of about 1 mile. In no case have blank pannings been obtained, the surface-prospects averaging about ½ ounce. The total length of reef, over which the rich gold has been obtained, is about 2,400 feet, but until the various shafts are connected at the 100 feet level, by drives admitting of an exhaustive sampling of the ore-reserves, it is impossible to prove the actual value of the lode. The present evidence all indicates the existence of an exceptionally rich and extensive ore-chute along the line indicated, the potential value of which is enormous.

About ¼ mile west of the Consort block of claims, a reef corresponding to the Middle White Reef has been located in a 15 feet shaft, yielding about ½ ounce of gold per ton. At an interval of about 1 mile, on the Blue Jacket West block of claims, a reef crops out, of which the strike and general characteristics correspond to those of the preceding lode. This reef, which is also known as the Middle White Reef, has been traced for about 1 mile, and opened up in several cuttings and two prospecting-shafts 18 and 75 feet deep respectively, where it is 2½ feet in width, samples from which assayed respectively, 1 ounce and 4 ounces of gold per ton (Fig. 20). Another reef branches off from the western end, south of the above, to which it runs in close proximity, the two reuniting about ½ mile to the east. The southern line, termed the Black and White Reef, from the appearance of the quartz which is stained in places with iron, has been opened up in a small 18 feet shaft, samples from

ton. A lode known as the
tance north of the Middle
traces of gold, and has not

quartz-vein averaging 1 foot
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distance in a north-easterly
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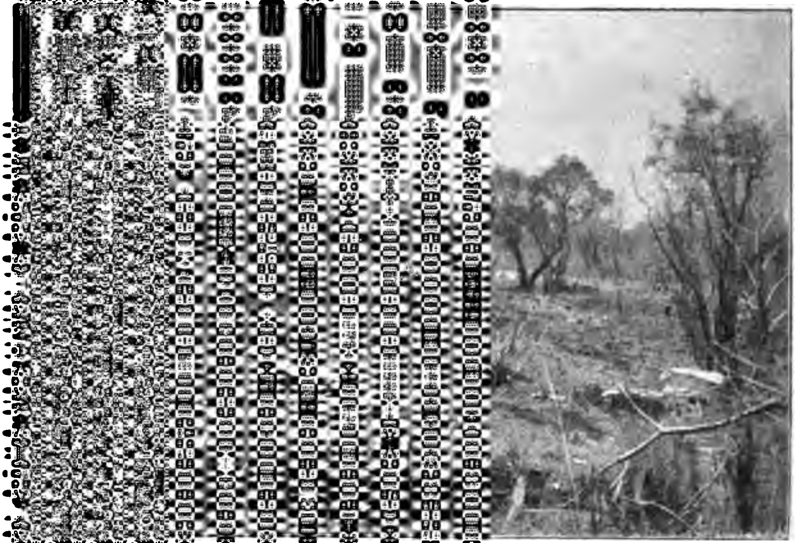
ing about 22 dwts. per ton.



75 Feet Shaft and Cuttings
, showing Line of Strike on
and Blue Jacket Hill are

a large dioritic dyke, known
vals along the northern side

st lode on the Blue Jacket
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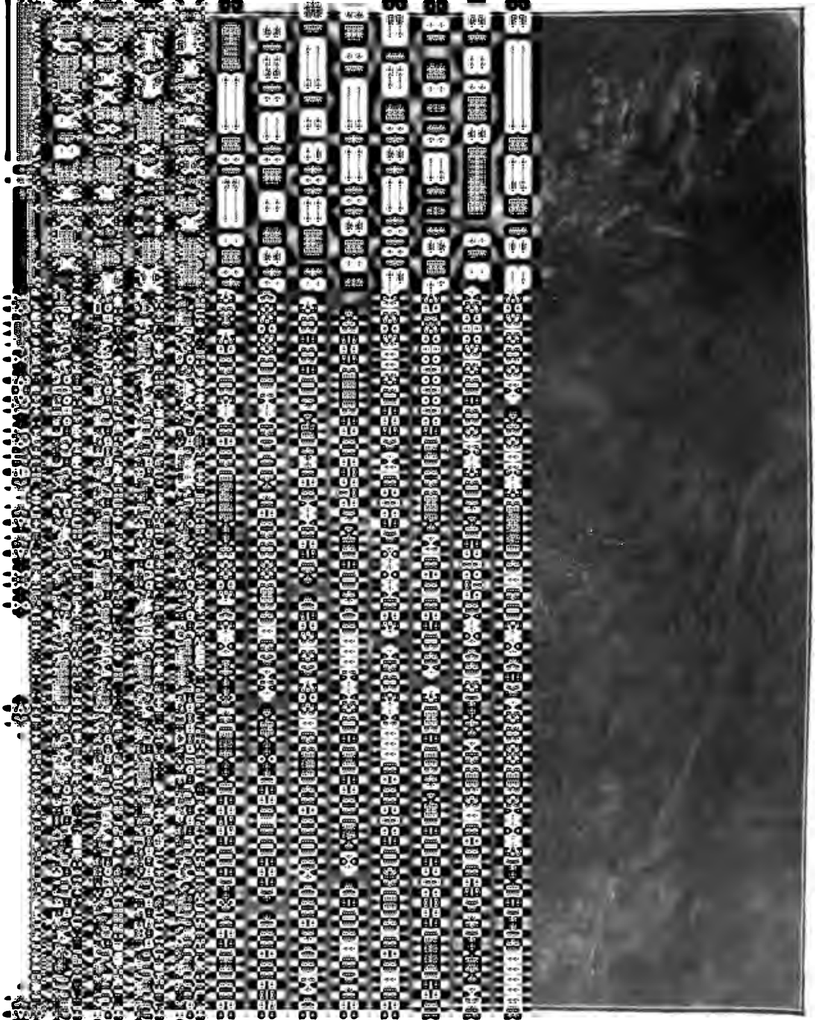

[illegible] 110 Feet Adit-level, [illegible]

[illegible] the quartzite. Numerous [illegible] outcrop, surface-prospects [illegible] gold per ton. An adit,

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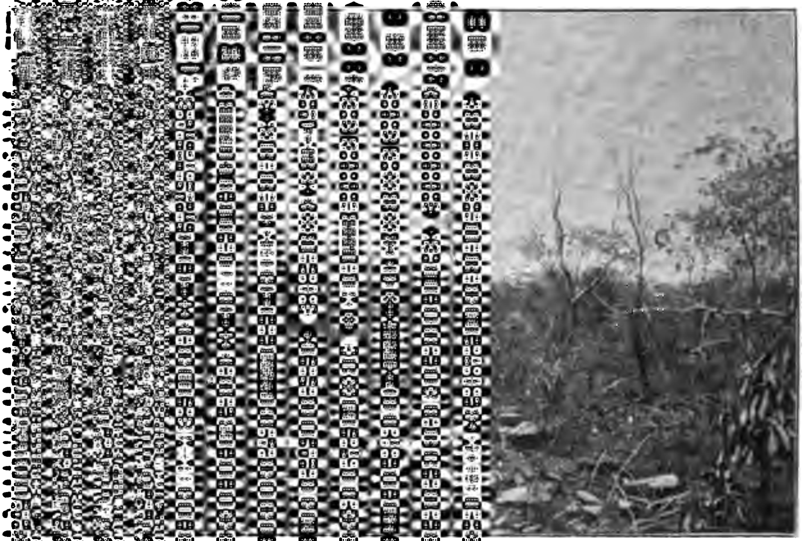


OF SHAFT AND CUTTINGS ON
JACKET WEST CLAIMS. THE
THE BACKGROUND.

aminated, amphibole-schists,
and the dyke. The reef is
highly auriferous zone, con-
the stone is first dipped in
metal to be distributed in
h the quartz, which is glassy
of silica having apparently
h secondary minerals are to
ld. Samples from this reef
e value across the 8 feet of
The quartz is essentially

free-milling and not at all slimy. Excluding the rich gold vein referred to, samples amounting to 380 tons, taken from the various reefs on the Blue Jacket Block B claims, were crushed in a crude manner, and yielded 551 ounces 12 dwts. over the plates, the tailings averaging about 10 dwts. per ton, giving a total average value of 1·97 ounces of gold per ton.

(6) The President Reef crops out about 1 mile to the west, and a little to the south of the South Dyke Reef, of which it may possibly be the extension. It has been opened up in two shafts of 100 feet deep, and one of 50 feet, besides numerous cuttings, and has an average width of 2 feet, assays giving about 1¼ ounces of gold per ton. It has been followed, intermittently, through the Blue Jacket West block of claims, for about 1¼ miles, including a length of about 2,500 feet over which it has not been possible to trace it. A rough crushing of about 1,500 tons is stated to have given 1,275 ounces over the copper-plates, the tailings retaining about 7 dwts. per ton.

Several promising reefs have been located to the north, on the Blue Jacket Block A claims, showing gold, but the author's prospecting operations have been mainly confined to the previously described lodes. In the Lawson and Shaw block of claims the reefs yield from 12 dwts. to 1¼ ounces of gold per ton, and on one line, close to the Blue Jacket block of claims, a reef is reported to have been found assaying 40 ounces of gold to the ton.

Commencing at the eastern side of the Range, those mining areas situated on the southern belt of hills will be next dealt with.

IX.—Southern or Spitzkop Belt.

(1) The Sutherland Reef is, in one respect, the most important mine in the district, although its returns from an economical point of view have not been very brilliant; but this is due to the locally broken nature of the strata, the neighbourhood having undergone considerable geological disturbance, and the lode (which in places has yielded thousands of tons running several ounces of gold to the ton) is very irregular and much thrown about. The principal point to be noted is that in this, by far from the most promising region of the range, the reefs have been proved auriferous to a depth of about 600 feet. At the 600 feet level, the lode is 8 feet in width and showing visible gold, averaging 13 dwts. per ton, the country-rock is soft talcose and hydromicaceous schists containing lenticular masses and stringers of white quartz with pyrites and gold, the latter mostly plastering the surface of the schists. This is a fact of which the importance cannot be overestimated.

(2) Shotover, Great Bonanza, and Bendigo Reefs. The reefs of these blocks are represented in Fig. 4 (Plate X.). A few prospecting tunnels and shafts have been made on the two first properties, the reefs located on the Shotover block being of a promising nature, whilst the lode on the Great Bonanza block is from 8 to 9 feet thick, with gold varying from 5 dwts. to 5 ounces per ton. The Bendigo reef has yielded 10 dwts. to the ton, the gold being distributed uniformly through the quartz.

No prospecting of importance has been done farther east along the above line until the property of the Murchison Range Exploration and Development Syndicate is reached, forming the western boundary of the Blue Jacket area, and that, together with the latter, has already been described (Fig. 5, Plate X.).

(3) The President Company, shortly after flotation, was amalgamated with the Steyne Estate and George Goch Companies at Johannesburg, all the working capital being absorbed by the latter concerns. There are several hundred tons of ore at grass estimated to run 1 ounce to the ton.

(4) A considerable amount of work has been done on the La France block, the Black Reef having been opened up to a depth of about 150 feet and a good deal of driving accomplished. The lode averages not less that 4½ feet, and is associated with metamorphic schists and traps (Fig. 6, Plate XI.). Some thousands of tons of ore have been crushed, running from ½ ounce to 23 dwts. of gold per ton, rich stringers being occasionally found, with traces of other metals. The Bosnia reef, which is apparently the extension of the above, promises well at the surface, but has not been developed.

(5) The Lawrence-Melatie block, on the Melatie river, a little to the north-east of La France block, contains a very promising Black Reef about 4 feet in width, curiously intercalated with layers of a white, friable to argillaceous, aluminous substance containing gold, and yields, at the surface, about 17 dwts. to the ton.

X.—NORTHERN OR ANTIMONY LINE OF REEFS.

(1) The Murchison Crown, French Bobs, Daisy and Quagga are the four principal properties at the eastern end of the northern line of reefs which are, however, free from antimony. The reefs dip almost vertically through metamorphic schists and quartzites associated with igneous dykes (Fig. 4, Plate X.). A fair amount of prospecting has been done, and some rich ore located, notably on the Murchison Crown block, where 2,000 tons have been raised, stated to average 2 ounces of gold per ton. Prospecting in this portion of the Range is exceedingly difficult, on account of the irregularity of the lodes, due to the disturbed nature of the strata in their vicinity.

(2) A good deal of development has been accomplished on the Gravelotte block. The antimony-lode has been sunk on to a depth of 100 feet, and yielded enormously rich ore, carrying in places 75 per cent. of pure stibnite assaying 5 to 18 ounces of gold per ton. Owing to the reef pinching out at the above depth, the work has been abandoned, although there is no reason whatever for supposing that this is other than a temporary narrowing of the fissure, due to the lenticular nature of the lode. The Black Reef has also been proved to a depth of about 250 feet, and has yielded from 1 to 3 ounces of gold per ton, but 12½ dwts. over a width of 4 feet may be taken as the fair milling return. At this depth, the ore is highly pyritic, and would probably pay the extra cost of roasting. The rocks of this line of reefs consist essentially of highly chloritic schists, slates and altered quartzites (Fig. 5, Plate X.).

(3) The Murchison and Free State blocks have been opened up to a considerable extent, especially the latter. The reefs, which contain antimony, average from 4½ to 6 feet in thickness and yield from 15 dwts. to several ounces of gold per ton. The Free State mine is at present supplying a 5 stamps battery with ore yielding 17 dwts. of gold per ton over the plates.

(4) The Sable Antelope and Melatie blocks have not been developed, but the surface-prospects are most promising, the lode located on the former showing an outcrop of about 4½ feet and yielding from 12 to 15 dwts. of gold per ton. The latter contains an ore-body about 6 feet in width but less uniformly auriferous, giving from a few dwts. up to over 1 ounce to the ton.

(5) Prospecting has been done on both the Selkirk and Crœsus blocks, more especially the former, on which several promising lodes have been opened up varying from 2 to 5 feet and yielding from 10 dwts. up to 2½ ounces of gold per ton, the country-rock being composed of highly siliceous strata (Fig. 6, Plate XI.). The writer has spent a considerable time in prospecting the reefs on the Crœsus block, which belong mainly to the Melatie series, and are mostly free from antimony. Outcrops, from 1 to 3 feet thick occur, yielding from 15 dwts. up to 2½ ounces of gold per ton, and should average about 1 ounce per ton.

(6) The Melatie series of reefs is typically developed on the Envicta and Lion blocks, which are situated to the south of the Kasteel Kopjes, and have been prospected to a limited extent. The reefs are characteristically irregular and lenticular in their outcrops, which vary from 1 to 10 feet in thickness, as is especially the case with the Lion reef. The

quartz is glassy and semi-transparent, an important feature being the even distribution of the gold-contents, which range from about 15 to 20 dwts. per ton. The Black Reef has also been located at Kasteel Kopjes, showing favourable surface-indications, but has not been opened up.

(7) The reefs on the County Down, Farady and Winifred blocks are characterized by the presence of antimony in varying quantities, rich chutes of gold being met with, as at the County Down mine, where prospecting has been carried on to a considerable extent, the reefs being proved to a depth of 100 feet and averaging 4 feet in width, with a varying yield from 10 dwts. to 2 ounces of gold per ton.

(8) The gold-belt at Witkoppie has a width of about 8 miles, the northern range, between Witkoppie and the neighbourhood of the Selkirk, being represented by a double chain of hills, more or less detached, trending to the north-east. Several outlying kopjes occur, such as the Lowes Kop, not far from the Melatie river (Fig. 7, Plate XI.). Two reefs occur on the Star block; the northernmost has a width of 3 feet in a 20 feet shaft, samples from which yielded about 15 dwts. of gold per ton : the quartz is glassy and opalescent in appearance, and a good outcrop is visible for some distance.

To the south, a Black Reef has been opened up in a 30 feet shaft, from which samples were obtained giving 1¼ ounces of gold per ton across a 4 feet lode, which runs for a considerable distance in close proximity to a large dyke of porphyritic basalt, the neighbouring schists and quartzites being highly metamorphosed. The writer obtained some interesting specimens of a curious brecciated, concretionary limestone, which covers large areas between the hills to a depth varying from a few inches to several feet (Fig. 7, Plate XI.).

No opportunity occurred of examining the Witkoppie, which, to all appearance, consists of an enormous vein of white quartz or quartzite surrounded by a country-rock of talcose and amphibole-schists. Rising to a height of about 500 feet, it forms an important landmark.

(9) The Letselanga and Caledonia constitute the easternmost blocks at present held on the Murchison Range. The quartz is white, glassy and opaque, containing copper-pyrites and iron-pyrites, and not unfrequently showing visible gold, samples yielding 1¼ ounces of gold per ton. The reefs vary from 2 to 3 feet in width, and some very rich deposits are reported to have been found, but owing to the remote position of the locality, it has not hitherto received the attention which it without doubt deserves.

XI.—VALUE OF THE REEFS.

The following important facts may be deduced from the foregoing statements :—

(1) That there are a number of localities on the Murchison Range, on which reefs, from 2 to 8 feet wide, have been proved to a depth of 100 feet, and contain rich chutes of ore (in some cases rich in antimony) yielding as much as 10 ounces of gold per ton, and these, in some instances, appear to be of considerable extent, although it is not principally on such that the economic value of this gold-belt depends.

(2) That there are numerous lodes, some of them containing antimony, which have been traced intermittently from 10 to 40 miles, and proved in many places to a depth of 100 feet, which yield from 1 to 2 ounces of gold per ton from ore-bodies, having an average width of about 3 feet.

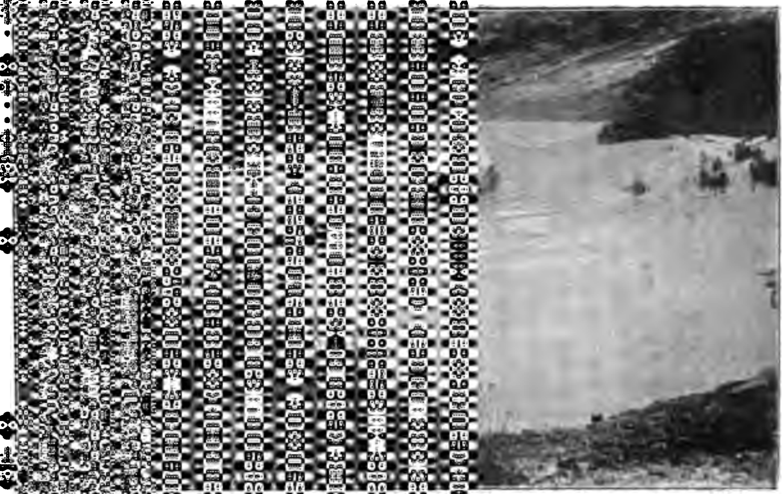
(3) That there are numerous lodes, mostly ferruginous, some proved to the depth of 150 feet, and others quite undeveloped, containing ore-bodies from 5 to 8 feet in width, which give a uniform yield throughout of 10 dwts. to 1 ounce of gold per ton, all the gold in these reefs being free-milling to a depth of about 150 feet, below which level auriferous pyrites occur.

(4) The price paid for the retorted gold ranges from £3 17s. 6d. to £4 0s. 2d. per ounce.

A very important characteristic of all these lodes is, that they are mostly gold-bearing throughout, and rarely yield a blank on panning, which indicates the possible occurrence of extensive bodies of low-grade ore. Numerous reefs, other than those described, have been located, from all of which gold has been obtained, though not in payable quantities. The richest reefs appear to belong to the oldest series of fissures, and are the most often associated with dykes and trap-rocks, probably of contemporaneous origin, the presence of which certainly favours the occurrence of gold in the reefs; precisely in what manner this influence operates has yet to be determined. In some cases, the Black Reef lines of fissure intersect at an acute angle, displacing the other richer reefs, and are in their turn intersected by younger lines of fissures, sometimes almost at right angles; the quartz in the latter, however, does not contain any gold. It is evident, therefore, in prospecting that too much importance must not be attached to the tracing, or otherwise, over long distances of a single reef, the main point being the identification of the various outcrops as contemporaneous with the line of fissures known to be auriferous, and this is of special importance where so large a number of reefs occur in such close proximity as in the Murchison Range.

ERATIONS.

he Murchison Range are not ed, and after making every nomic mining which existed 250 miles from the nearest treating and recovering the e failures rests on the com- reatly deficient in working nous. The general policy g out all the rich ore from that of lower grade till the the past, have until quite n the development of these to show signs of activity.



ETSITELE RIVER, DURING THE

oria has now been brought to chison Range, an approach of machinery, etc., to the y-terminus to Leydsdorp, is hat portion descending from to the Letsitele, it is very the rate of £2 10s. per ton. right along the Range to the

Witkoppies, the road is flat and good, presenting no difficulties. The Selatie railway will prove of incalculable benefit to the district, and will facilitate development enormously, as the Murchison gold-fields will thereby be placed in direct communication with Delagoa Bay, a distance of about 200 miles, according to the surveyed track of the line, the permanent way of which has been laid down to the Selatie river-bridge, distant 125 miles from Delagoa Bay. The completion of the line is in abeyance, pending the results of litigation between the Government and the company ; but this is likely to be speedily settled, as the former are anxious to effect the completion of the line as soon as possible (Sketch Map, Plate XII.).

(3) *Native Labour.*—This item is of the greatest importance from an economic point of view, and one with regard to which the Murchison Range enjoys special advantages, owing to its situation in the centre of the most thickly native-populated district of the Transvaal. The last estimate, taken about 1890, gave approximately 80,000 males, 100,000 females and 200,000 children. The two chief tribes are the Basutos or Magatis, and the Magwambas or Knob-noses, the latter being especially finely-built men and excellent workers. The natives are somewhat independent, but are willing to work, and if treated well, respectful and obedient. They much prefer to work in their own district rather than migrate to the Rand, and consequently there is a most important reduction in the wages paid on the Murchison Range over those paid in Johannesburg, the latter ranging from £2 10s. per month to £3 15s. in the case of picked natives, whereas from £1 10s. to £2 5s. is paid on the Murchison Range, and exceptionally good Kaffirs are paid £2 10s. This difference would reduce the working costs of a company with a large area to develop, requiring the employment of hundreds of natives, by several thousands of pounds per annum.

(4) *White Labour.*—This, if anything, is a trifle more costly than on the Witwatersrand, ranging from £20 to £30 per month. Carpenters and blacksmiths are paid £30 per month.

(5) *Water.*—There is plenty of water in the district, all rivers capable of supplying the Range with water being indicated on the map (Fig. 1, Plate IX.).

The Melatie river cannot be relied upon to supply many stamps, as during the dry seasons only the lagoons contain water, but it is probable that wells sunk in its vicinity would yield a fair supply.

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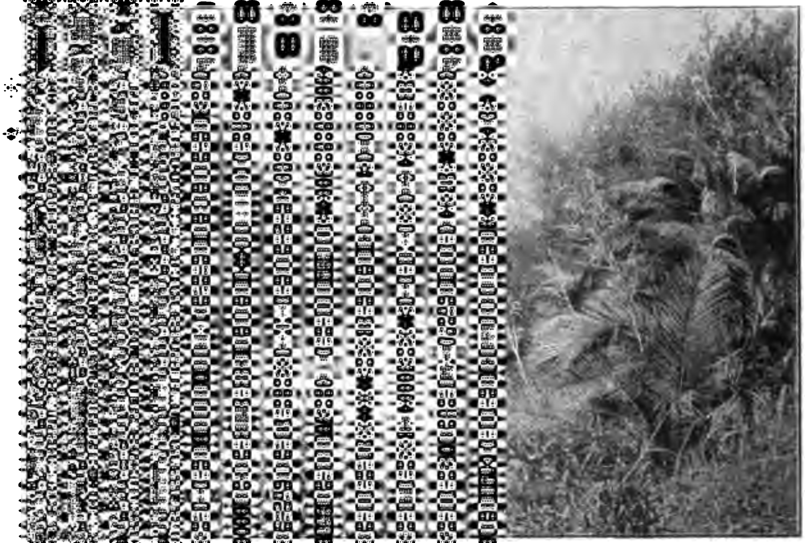

NG WESTWARD, 21,450 FEET
T HILL.

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fall of nearly 200 feet can
Murchison Range. This
cubic feet per minute during

the rainy season ; it has an average fall per mile over the 60 miles of 21 feet, while, for a few miles in the vicinity of the Drakensberg, there is a fall of 60 feet per mile. Although practicable, some difficulty would be experienced in bringing the water over the first few miles, owing to the broken nature of the country. This could be more easily accomplished in the case of the Letsitele and Thabine rivers : a similar altitude above the Murchison Range being attainable at points 7 and 10 miles respectively above their junction. From thence the water could be supplied by gravitation to the whole of the Murchison Range. With the exception of a few miles in the Thabine valley, slightly below the level of the Murchison, there are no localities where extra pressure would have to be dealt with. The water is of great purity.

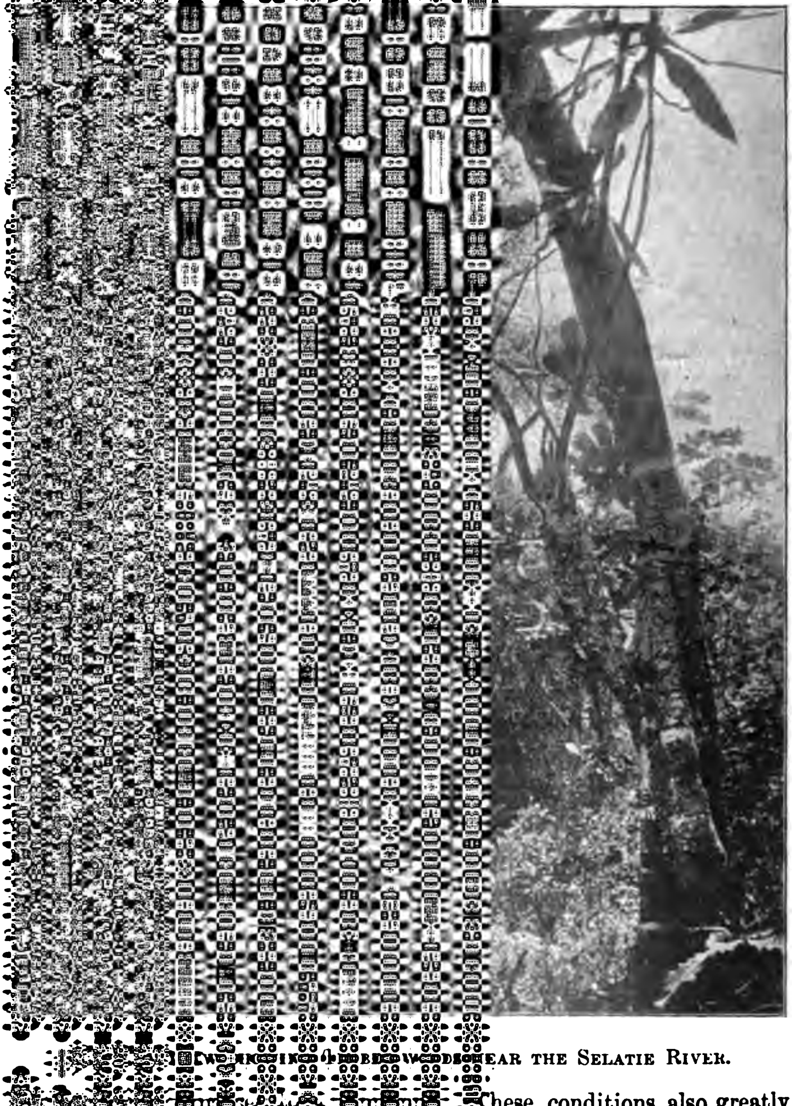
(6) *Fuel and Timber.*—The employment of coal is, at present, too costly, but supplies will be available on completion of the Selatie railway.

The matter is not one of consequence, as enormous quantities of wood-fuel of excellent quality are obtainable at a very low cost.

Timber of various kinds, well suited for mining purposes, grows in abundance, especially in the Woodbush hills, where the wood is sawn into planks and beams by sawyers who supply the mines with timber. The yellow-wood tree is useful for many purposes ; the wood being loose-grained and the tree growing tall and straight, 1 inch planks have been sold at Leydsdorp in lengths of from 15 to 30 feet at 7½d. per running foot. The white pear-tree, which grows in the same locality and is supposed to be stronger than the yellow-wood, can be obtained in beams measuring 3 by 9 inches, in lengths of from 14 to 20 feet at 11½d. per running foot ; a waggon-load of 50 beams averaging 17 feet in length, cost 4s. per beam delivered at Leydsdorp. Numerous trees abound on the Murchison Range, such as the mapane or turpentine tree, boekenhout, acacia, wachteenbietje, etc., which are very serviceable for light timbering. A tax of £1 per waggon-load of timber cut on Government ground is imposed, but the authorities do not press this point.

7. *Working Costs.*—An important character of the Murchison Range, and one which will, to a very great extent reduce the cost of mining, is the position occupied by many of the reefs which strike along the hill-tops with an approximately vertical dip, in such a manner as to allow of "backs" of from 100 to 600 feet being opened up by adits, by means of which the ore can be transported to the battery by gravitation. This is well illustrated in the case of the Blue Jacket Hill, on the slopes of

[illegible] for reception of the water [illegible] evation as will allow of the [illegible] second battery at the other [illegible] miles, and which will reduce



[illegible] EAR THE SELATIE RIVER.

[illegible] These conditions also greatly [illegible] the opening up of the reefs, [illegible] rapidly and economically by [illegible]

8. *Sinking.*—No development, other than small prospecting-shafts, tunnels, etc., has been accomplished on the Murchison gold-fields for many years; but the following particulars as to working-costs are recorded by Mr. A. R. Sawyer. A main shaft, 6½ by 10½ feet within the timbering, was sunk to a depth of 93 feet, the top of the shaft being securely timbered and raised to a height of 4½ feet. The collar was made of 1 foot by 1 foot timbers, and the sets placed from 4½ to 5 feet apart, the timbers from 7 inches to 8 inches wide and 9 inches deep, and well jointed together. From 90 to 100 side-timbers, about 4 inches in thickness, were put in behind each set: mapane wood, growing close at hand in abundance, being used throughout. The shaft was sunk during the rainy season, a circumstance which hampered the work. The cost was: labour, £431 13s. 1d.; material, £64 13s. 10d.; or a total of £496 6s. 11d., for the 93 feet sunk, equivalent to £5 6s. 8d. per foot.

9. *Driving.*—The average cost of driving, through rocks of various hardness, is given at from £1 15s. to £2 16s. per foot; the cost of an adit-level, 384 feet long, with an open cutting of 89 feet, making 473 feet in all, driven partly in chloritic schists and partly in talcose quartzites, amounted to £1 9s. 11d. per foot, including labour and material. The above drift was done in the beginning of 1891, and to-day could be done more cheaply.

The main factor to be considered is the enormous progress that has been made in the Transvaal in the treatment and recovery of gold, and of this the Murchison Range will now reap the full benefit, together with that accruing from the important increase in the facilities for transport, etc., due to the recent opening of the Pretoria-Pietersburg railway. With an average total working-cost of 27s. per ton for the Witwatersrand, one can safely predict an average cost of not more than 32s. 6d. per ton of ore treated on the Murchison Range. Taking the average total recovery even at 12 dwts. of gold per ton, worth 3s. 10½d. per dwt., this would give a value of £2 6s. 6d., which, less a cost of £1 12s. 6d., represents a net profit of 18s. per ton for ore of lower grade. Taking the total average value of the gold recovered at 1 ounce per ton (a very moderate estimate), we arrive at a net profit of £2 5s. per ton, a result which would compare favourably with the best mines on the Witwatersrand.

XIII.—MINERALOGY.

In addition to gold and antimony, the following minerals of economic importance are to be found in the Murchison Range district:—

(1) *Copper.*—This metal occurs in great quantities in the neighbourhood of the Palabora, where there are extensive old workings of an unknown age, and from these thousands of tons of ore have been removed. The matrix consists essentially of a highly crystalline white calcareous to siliceous rock containing magnetic iron-ore associated with sulphides, oxides, silicates and carbonates of copper, which the Kaffirs used to smelt for the purpose of making various copper ornaments.

(2) *Mercury*, native and in the form of cinnabar, has been found north of Witkoppies, along the line of junction between the granites and schists, associated with metamorphic sandstones and porphyrites.

(3) *Tin* occurs as stream-tin in a locality shown on the map (Fig 1, Plate IX.) at the Great Letaba river, and also in veins in the granite, which contains large orthoclase-crystals.

(4) *Mica*, in the form of muscovite, occurs in considerable abundance south of the Selatie river in large slabs varying from 6 by 9 inches up to sheets 18 by 10 inches. The manner of occurrence of the mica is interesting. A section from north-west to south-east through the rocks exposes the following varieties (Fig. 8, Plate XI.):—Granite, gneiss, syenite, minette, felsite, syenite, with large mica-crystals gradually passing into a micaceous granite, in which bands of mica occur, the rock acquiring the form of a porphyry. Thin quartz mica and felspar occur in parallel zones, not due to foliation, the crystals being mostly idiomorphic, apparently owing to the solidification of the original magma having taken place under conditions favourable to the crystallization of the constituent minerals in a selective order. There are, however, in the vicinity true gneisses showing marked foliation.

(5) *Diamonds.*—Diamantiferous wash occurs in the Thabine district, where one or two stones have been found, but no prospecting has been done, and the original "pipe" of blue-ground has not been located.

XIV.—OTHER GOLD-FIELDS.

The other gold-fields of the Zoutpansberg district are of smaller area, and consist of the following:—

(1) *The Klein Letaba* gold-fields are about 20 miles in extent. They run approximately parallel to the Murchison Range, and are situated

about 50 miles northward. The auriferous formation is similar to that of the Murchison Range, but is more broken by granitic intrusions. The Sutherland range of hills have been prospected and opened up to a small extent only. Some very rich chutes were worked at the Birthday and Ellerton mines, which were, however, closed down on exhaustion of the high-grade ore. The gold-fields are watered by the Klein Letaba river, and are well wooded.

(2) *The Molodotsi* gold-fields, situated on the river of that name, comprise a narrow strip of auriferous schists, on which no development of importance has been accomplished.

(3) *The Woodbush and Haenartsburg* gold-fields are situated outside the Low Country, as shown in the map (Fig. 1, Plate IX., and Fig. 8, Plate X.), and consist of quartzose sandstone and schists associated with granitic intrusions in which numerous auriferous quartz-reefs have been located, but mining has not been carried on to any extent.

(4) *The Marabasstad and Smitsdorp* gold-fields are near Pietersburg, and since the advent of the railway have been showing renewed signs of activity. They consist of schists similar to those of the Murchison Range, and some very promising reefs have been proved to depths of from 50 to 150 feet. Rich chutes have been opened up at the Roodeport and Ersteling, and the outlook is decidedly promising.

According to official returns, the total amount of gold recorded from the whole of the Zoutpansberg district up to the present time is about 65,000 ounces, worth £250,000.

XV.—Other Minerals.

The district of Zoutpansberg is rich in iron, copper, lead and coal, and probably also in tin, silver and rock-salt, promising indications of diamonds occur in other localities, and native sulphur has also been located.

References to Fig. 9, Plate XI. —Diagrammatic Section across the Main Lines of Reefs of Blue Jacket Hill, from North-west to South-east.

1. Talcose and hornblendic schists.

2. Banded black, red and brown ferruginous and siliceous slates.

a. Ferruginous cellular quartz-reef, 4 to 10 feet wide, carrying visible gold. The average yield is 12½ dwts. of gold per ton.

3. Dark hornblendic slates and schists.

b. White sugary quartz-reef, carrying about 1 dwt. of gold per ton.

4. Ferruginous metamorphic slates, micaceous and hornblendic.

c. Quartz stringers, carrying about 9 dwts. of gold per ton.

5. Hornblendic, micaceous and talcose schists, with traces of chlorite.

d. White and green banded quartz-reef, containing a rich vein of coarse gold, indicated by dotted line, showing slickensides and transverse dislocations. The yield is from 50 ounces of gold per ton.

e. White sugary quartz-reef, carrying visible gold, about 1 ounce per ton.

6. Soft contorted schists, hydro-micaceous, talcose and pyritic, with hornblende and tremolite.

7. "Manipa Bar," an intrusive dyke, much decomposed and fissured, apparently a hornblende-augite-mica-diorite, with a width of 35 feet.

8 and *f.* Massive reef of hard, compact, bluish-green translucent quartz, 8 feet in width, showing fine visible gold on the foot-wall of the dyke.

g. Auriferous zone, showing abundant finely-divided crystalline gold disseminated in grains and veinlets through the quartz, with a yield of 5 ounces per ton.

h. At this point, the reef passes insensibly into a massive, cherty, foliated quartzite.

9. Hard schistose quartzites.

10. Green schistose quartzites, with beds of laminated and arenaceous schists.

11. Hornblendic and micaceous schists.

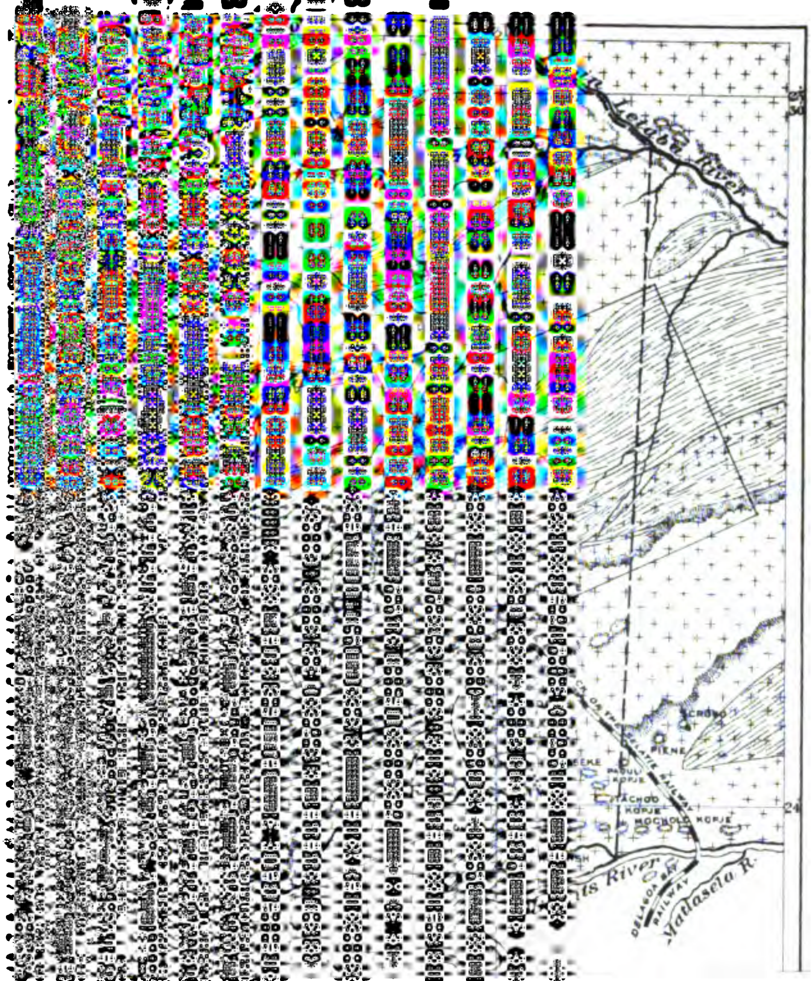
12. Soft talcose and micaceous schists.

Mr. ARNOLD LUPTON (Leeds) asked Mr. Steuart to give the members some idea of the amount of material which had been crushed in order to obtain the results of from 1 ounce to 2 ounces of gold which he had mentioned. He supposed that the beds of schists had been crumpled, so that the outcrop of the veins occurred again and again. He did not know how else that long series of vertical reefs could have been produced.

Mr. DOUGLAS S. S. STEUART said that a small 5 stamps battery of inferior quality was employed with 300 pounds stamps. A crushing of 400 tons from the various reefs had yielded 586 ounces over the copper-plates, and the tailings contained about 12 pennyweights per ton. The country from the Drakensberg to the eastward consisted of vertical schists, which he imagined were of Archæan and not of Cambrian age, and he assumed that originally they were lying horizontally. The schists were tilted vertically in anticlines and synclines, and the anticlines had been denuded.

The PRESIDENT moved a vote of thanks to Mr. Steuart for his interesting paper, which was cordially approved.

The following paper by Mr. E. G. VECQUERAY on "The Nodon-Bretonneau Process of Seasoning and Preserving Timber and other Fibrous Substances by means of Electricity" was read as follows :—


Letaba River
PIENE
PAOLI KOPJE
STACHOD KOPJE
MOCHOLO KOPJE
SELATIE RAILWAY
DELAGOA BAY RAILWAY
its River
Matlasela R.
24

THE NODON-BRETONNEAU PROCESS OF SEASONING AND PRESERVING TIMBER AND OTHER FIBROUS SUBSTANCES BY MEANS OF ELECTRICITY.

By E. G. VECQUERAY.

In the Nodon-Bretonneau electric seasoning and preserving process, the timber is placed in rectangular wooden tanks of various lengths (suitable to the planks or baulks to be treated), and about 3 feet wide by 3 feet deep. A serpentine copper steam-pipe is fixed in the bottom of the tank, and the solution is kept at a temperature of about 100° Fahr. by the circulation of steam. Above the steam-pipe, there is an open-grid false-bottom entirely covered by sheet-lead, which is connected with the positive pole of the dynamo.

The timber to be treated is placed on the sheet-lead, and above the timber are placed porous trays, consisting of rectangular wooden frames, the bottoms of which are made up of felt and canvas, supporting another sheet of lead, which is connected with the negative pole of the dynamo.

The solution of *boro-resinate de soude* is then pumped into the tank, until the timber is immersed to within 2 inches of its upper surface, and pure water is placed in the porous trays to ensure good connexion between the timber and the negative pole, and to assist the process of osmosis. When the current of 110 volts is started, unless the timber is very green and moist, only a small current is observed to pass through, but it gradually increases, and when it reaches a given number of ampères per cubic foot of timber, part of the solution is pumped out. The resistance being thus increased the current falls, but increases again as before; and the process is repeated until the timber is entirely out of the solution, and yet the current indicates the given number of ampères required.

As may be expected, the duration of this operation varies according to the density, thickness and greeness of the timber.

After the timber has been removed from the tank, it is dried in the open air and warm chambers, the process, in all, taking from 1 to 2 months, according to the nature of the wood, instead of years, and at the end of this very short time, the timber so treated is in better condition than naturally-seasoned wood.

Theory of the Process.—Scientists are not in agreement as to the theoretical explanation of the ascertained facts of the process. The technical advisers in Paris state that the process is that of "electrical osmosis," or as Prof. Lippmann prefers to call it, "electro-capillary attraction."

The action which takes place in the wellknown physical laboratory experiment with the divided cell and wet cotton, is parallel on a small scale, with that which occurs in the treating tank. In detail it is as follows :—A glass cell is divided by a watertight diaphragm, each compartment is partially filled with water, and a wetted cotton or woollen thread passes from one division to the other, both ends being immersed. When a current is passed through the thread, one pole being in each compartment, the water travels in the direction of the current through the thread, and a difference in level of the water is soon produced.

Comparing the two processes, the timber takes the place of the diaphragm, and its constituent fibres take the place of the thread, and therefore the greener the timber, the quicker the process.

Practical Advantages.—The decay of timber is caused by the putrefying of the sap, and the consequent formation of fungi. Seasoned timber is that in which the sap has been dried up by exposure to sun and wind for long periods, varying with the density and porosity of the timber. It is claimed that the action of the Nodon-Bretonneau process removes the sap.

In an experiment, a piece of oak was taken and sawn in half; one half was treated and the other half left untreated. Both pieces were partially embedded for 8 months in a moist manure-heap. After this period, while the treated piece was absolutely unaffected, both at its most vulnerable point, namely, between wind and water, and also all over the part entirely covered by the manure, the untreated piece was, on the other hand, rotten and useless.

The chief cause of warping is the uneven drying of wood, caused by unequal distribution of moisture. In the Nodon-Bretonneau process, the moisture disappears, and the writer would repeat in this connexion, that the wetter the wood when treated, the quicker and more effectual is the seasoning. A strip ¼ inch thick was cut from the top of a piece of beech measuring about 12 by 9 by 3 inches, and the thin piece so obtained was left in the warm tank-room for a time, and then placed at a window with a hot sun playing on it. After this, the piece was placed on the original block, and it had not warped or twisted a fraction, even after so severe a test. [This sample was exhibited to the members.]

In another experiment, made in Paris, a framed door was made up without pins to hold the mortices, glue only being used. It was left in the open air for nearly a year, exposed to every climatic variation of rain, snow, and the full glare of the summer sun of Paris : it has neither warped nor twisted, and not one of the joints had opened.

Musical instruments, particularly violins and the sounding-boards of pianofortes, require to be made of wood of the most perfect soundness and dryness. Pianoforte-makers find that even soft woods treated by the Nodon-Bretonneau process are better than hard woods seasoned by ordinary methods. A violin-maker is now using practically nothing else, and has obtained results in sonority, hardness and closeness in texture, never before possible.

Members may ask "What have violins to do with pit-props?" and he would answer that "What is useful in so delicate a line of workmanship, requiring extreme strength with apparent fragility, is equally valuable where the roughest timber is concerned."

Maritime pine and grisard [samples of both of which timbers were exhibited to the members] have never hitherto been capable of being naturally dried, and consequently had practically no commercial value. A sample of maritime pine was cut on May 10th, 1897, on May 28th it was seasoned, and it is now fit for general joinery purposes.

Two pit-props were kindly sent for treatment by your President, both props cut diagonally across the centre. The first prop was placed in a small tank on May 2nd, 1899, in which some experimental tests had been made for staining wood by this process ; although the tank had been very carefully washed out and a new solution made previous to treating the prop, a certain amount of discoloration was found. A second prop was requested, and arrived on May 13th, 1899 : it was placed in the large tank, where no colouring-matter had been put. Both samples can be examined by the members at Charlton, and a decided difference will be observed. The treated props are in a better condition than the props left untreated, which have opened up considerably, although they have been left in the ordinary atmosphere under cover, while the treated props have been subjected to an excess of heat, so as to get them as dry as possible in the short time since they were treated.

Mr. E. G. VECQUERAY said he trusted, in spite of all imperfections on his part, that the members would feel so interested in the problem and the results mentioned in the paper that they would decide to see the actual working of the process at Charlton, where a tank was ready for treating several pit-props, secured for the proposed visit. He also hoped to show the effect of the treatment of timber, as seen through the microscope, namely, that the walls of the sap-tubes are rendered denser and stronger by the process, while the tubes themselves are left clear. It was found when preparing the slides that the shavings from the naturally dried timber readily fell to pieces, while those from electrically seasoned timber showed great tenacity; and especially was this the case in samples from the pit-props supplied by the President.

The PRESIDENT (Mr. J. A. Longden) said that at Stanton collieries with an output of 1,000,000 tons per annum, about 300,000 props were used costing about £10,000. From these figures, he estimated that the value of the timber used in the coal-mines of Great Britain was probably about £2,000,000 per annum. If the life of pit-props could be extended 50 per cent. by drying them, it would also lessen the liability to accident. It appeared to him that there would be a great advantage in adopting seasoned timber for use in mines.

Mr. ARNOLD LUPTON (Leeds) asked the cost of seasoning various kinds of timber by the proposed method.

Mr. LAWRENCE WEAVER thought that the cost was about 3d. per cubic foot.

Mr. A. SOPWITH (Cannock) said that the cost of mining timber did not exceed 1s. 3d per foot, and an extra 3d. would increase the cost 25 per cent. An important question arose as to the cost of an installation necessary to treat large quantities of timber.

Mr. ARNOLD LUPTON thought that pit-timber cost about 8d. per cubic foot.

Mr. M. WALTON BROWN wrote that the solution employed in the Nodon-Bretonneau process consisted of 10 per cent. of borax, 5 per cent. of resin, ¾ per cent. of carbonate of soda, and 84¼ per cent. of water. The electric current had a tension of 110 volts, and varied from *zero* to 5 ampères, and the treatment of the timber was completed in from 5 to 8 hours, except the drying of the timber in the open air in summer, or by stoving it at a temperature of 60° to 70° Fahr. in winter, which removed the moisture. At the end of 10 or 15 days, the timber could be used for any purpose. He was informed that the solution could be repeatedly used, as only a portion of it was absorbed by the timber, which appeared to gain slightly in weight. It was stated that the electric current transformed the pith into an insoluble and indestructible substance, analogous to resin, and rendered the timber impermeable to water.

The PRESIDENT proposed a vote of thanks to the writer of the paper, which was cordially approved.

Mr. HARRY RHODES read the following paper on "The Use of Slow-moving Belt-ropes in Shafts:"—

THE USE OF SLOW-MOVING BELT-ROPES IN SHAFTS.

By HARRY RHODES.

The simplest and most economical method of transmitting power in mine-shafts is one of the most important questions which mining engineers have now to consider and solve, having regard to the increasing depths at which coal has to be worked and the necessity of utilizing the shafts for the purpose of winding coal to the fullest extent. The means principally in use for this object are as follow:—(1) steam, (2) compressed air, (3) electricity, (4) fast-running ropes, and (5) slow-running ropes.

The disadvantages of steam-transmission are the low efficiency, and high cost of installation and maintenance. The engine-houses underground require extensive and expensive excavations, and must be arched or otherwise made secure, owing to the heat and moisture given off by the engines. The air in the immediate vicinity of the engines is unpleasantly heated, and the exhaust-steam, unless condensed, injures the lining of the shafts and passages leading thereto. There are also the risk of fire, and the difficulty of dealing with the exhaust-steam, which if not piped to the surface or completely condensed (which is generally impracticable) renders the utilization of the upcast shaft almost impossible.

Compressed air is expensive both in installation and maintenance, and its efficiency is lower than steam. In addition to the expense of the compressor at the surface, there are the same pipes in the shafts as with steam, and the same engines underground, thus practically doubling the expense in labour and stores as compared with steam. Of course, against these manifest disadvantages must be placed the fact that though low in efficiency it is a very safe and useful power.

Electricity is free from many of the above-cited disadvantages. The supervision is, however, somewhat costly and requires great care as in addition to a steam-engine and a delicate piece of machinery (dynamo) on the surface, there is another delicate machine underground running at a high speed; the cables also require careful watching and attention. The great charm of electricity is, of course, its high efficiency and the ease with which the power can be carried to any point at little cost and with great rapidity. In fiery mines, however, its use must be attended with some risk, simple and attractive as it is, and the writer therefore ventures to describe what he cannot help thinking as the simplest and most economical system of transmission, that is by engines on the surface transmitting power through a strap-rope.

Fast-running strap-ropes, unless transmitting power for main-and-tail-rope haulage, necessitate extra underground gearing with all its disadvantages, apart from the danger of serious damage being caused by a breakage of the rope in the shaft even if it is cased, and the rapid rate of wear of the ropes.

With slow-moving belt-ropes the whole of the gearing is on the surface, and is easily accessible for repairs and renewals. They are comparatively cheap to install and maintain, and if properly cased a break in the shaft does little damage.

The installation of a plant for the transmission of power by slow-moving band-ropes requires the consideration of the following details:—(*a*) Engines, (*b*) spur-gearing, (*c*) driving-pulleys, (*d*) guide-pulleys at the surface and at the pit-bottom, (*e*) clutch-gear for transmission of power to haulage, (*f*) straining-gear, and (*g*) ropes.

Engines.—The engines should preferably have two cylinders so as to ensure uniformity of speed. Compound, condensing, or other engines of the most approved type, should of course be used when there is sufficient steam-pressure.

Spur-gearing.—Gearing at a ratio of about 9 to 1 is found to answer well in practice, giving with a 7 feet driving pulley a speed of 3¼ miles per hour. The gearing is best effected in two stages, as it does not require such large spur-wheels, which are awkward to get into position and expensive.

A steam-engine which gives efficient results is of the locomotive type (Fig. 1, Plate XIII.), with slot-cranks set at right angles, etc. The end of the crank-shaft overhangs the bed at each side, with a flywheel 6 feet in diameter, keyed on one end, and, on the other, a pinion-wheel with 27 teeth shrouded on one side. The pinion gears into a spur-wheel 8 feet in diameter on the second-motion shaft with 100 teeth. This gearing gives a ratio of 3·703 for the first stage. A pinion on the second shaft has 20 teeth, and is very strongly made (in halves) and shrouded on both sides up to the pitch-line. On the third-motion shaft is placed a spur-wheel with 80 teeth, and a driving-pulley 6 feet in diameter on the tread. This engine runs at 120 strokes per minute.

Driving-pulleys.—It will be observed from Fig. 2 (Plate XIII.) that the driving-wheel and spur-wheel are strongly bolted together, thus practically forming one wheel. This saves any torsion on the shaft, which simply becomes a carrier and need not be unnecessarily weakened by deep key-beds. The tread of the driving pulley is loose, and is made of cast steel with a radius of 4⅞ inches. The rope is taken 3½ turns round this wheel, and lies in the position shown in Fig. 2. In the present case, the rope is ⅞ inch in diameter, and will be replaced by another rope 1¼ inches in diameter in the course of a few days. This plant is referred to as No. 1 colliery in the table of costs.

Helical wheels for gearing give very much smoother running than ordinary gear, but machine-moulded teeth can now be made to run so silently that it is questionable whether helical-gearing is worth the enhanced cost. All gearing should be shrouded up to the pitch-line.

Many varieties of clip-pulleys or groove-pulleys have been used for endless-rope driving, but they have nearly all been discarded in favour of C, or taper-throated pulleys. The pulley should be made in halves, with loose wearing segments bolted in. A great diversity of opinion exists as to the most desirable shape of the treads of these pulleys, and Figs. 2 to 11 (Plate XIII.) illustrate the various types employed. From experience, the writer prefers the type of pulley shown in Fig. 2 (Plate XIII.), and at Messrs. John Brown & Company's collieries, with which he is connected, there are 20 pulleys of this class at work, driving about 25 miles of ropes. The average life of these segmental treads is about 9 months. At No. 4 colliery (see appendix), the pulley shown in Fig. 4 (Plate XIII.) has been replaced by that shown in Fig. 5 (Plate XIII.), and the life of the ropes has been increased by 2 months.

Mr. Henry Fisher, of Clifton Colliery, near Nottingham, who has had great experience in endless-rope haulage, recommends the pulleys shown in Figs. 9 and 10 (Plate XIII.), which are intended for ropes 1¼ inches and ⅞ inch respectively in diameter; these wheels however run horizontally, whereas all the others shown in Figs. 2, 3, 4, 5, 6, 7, 8, and 11 (Plate XIII.) run vertically as shown in Fig. 2.

The Cadzow clip pulley is much used in Scotland and the North of England, and is illustrated in Fig. 8 (Plate XIII.). At first sight, it would appear that owing to the wedging action the rope would be rapidly worn, as the whole of the power is applied to a length of rope represented by about half the circumference of the pulley; however, the costs recorded in the table show that it gives good results.

Guide-pulleys.—The guide-pulleys at the top and bottom of the shaft should be as large as the driving-wheel to give efficient results, but their size is generally dependent upon the amount of room available. They may be placed one above the other (and where this can be done, it is perhaps the best method), or side by side some distance (at least 2 feet) apart. In either of these positions, the shafts and bearings do not require any mention; in many cases, however, the ropes have to pass down the shaft not more than 5 or 6 inches apart, as shown in Fig. 12 (Plate XIII.), and in such cases both pulleys must be placed on the same shaft. A common method of doing this is to bush each pulley with brass and run them loose on a shaft which is carried in cast-iron bushes, allowing it to turn either way if one pulley becomes jammed.

The disadvantage of this method is that the full or pulling-rope pulley wears its portion of the shaft and bush very much quicker than the other. This sooner or later allows the flanges of the pulleys to rub together, throws the rope out of position, and introduces additional side-friction on the driving-pulley. To obviate this difficulty, the full rope-pulley, *A*, should be keyed on to its shaft and the shaft mounted in ordinary pedestals, Fig. 12 (Plate XIII). The empty rope-pulley, *B*, is bushed with brass, *a*, and secured on the shaft by the collar, *b*. At Aldwarke Main and Car House collieries, pulleys have been run in this manner for 10 years without requiring adjustment.

Clutch-gearing.—When the band-rope has been carried to the bottom of the shaft it is taken a short distance inbye, and passed a few turns round a pulley similar to the one on the surface. The number of turns is usually the same as on the engine. This pulley is mounted on a shaft on which are placed driving-pulleys or spur-gearing for transmitting power in the required direction.

The usual practice is to have the band-rope constantly running, and the various branch-pulleys capable of being put in and out of gear by clutches. Where the work required from a branch-rope is regular, such as driving a pump, these clutches may be of the jaw type, as they are not so expensive as friction-clutches. Cone-clutches have been tried, but are not to be recommended as they often jam, and are then extremely difficult to get out, and, in some cases, they have had to be broken in order to set them free.

In haulage, where the ropes have frequently to be started and stopped, it is important, having regard to the life of the ropes, that they should be started and stopped with as few jerks and strains as possible.

Suppose that we have at a standstill, a length of endless-rope haulage fully loaded and the band-rope moving at its normal speed. On putting into gear with a jaw clutch, the whole system, perhaps thousands of feet in length, has suddenly to begin travelling at the same speed as the band-rope, and consequently something very often breaks. On the other hand, jaw-clutches cannot be got out of gear without stopping the rope.

To overcome these disadvantages, friction-clutches have been designed, and of these there are many excellent types in use. The principle of the action of all such clutches is a kind of expansion-ring fitted in segments and secured to the driving shaft, and these may be expanded or contracted by means of right-and-left-hand screws or wedges upon a bearing-surface cast upon the side of the driving-pulley.

The Fisher clutch (Fig. 13, Plate XIII.) consists of a driving drum firmly secured on the shaft. Around the periphery of this drum are arranged a series of segments, usually three or four, connected by means of right-and-left-hand screws. An arrangement of levers is provided by which these screws may be turned: turning them one way tightens the segments on the drum, and the other way loosens them. In the centre of the segments is an oblong hole in which a square pin is placed, and the other end of this pin passes into the arms of the driving-pulley. The drum is keyed to and revolves with the shaft, and the pulley is bushed with anti-friction metal and runs loose on the shaft, but is secured to the segments by the pin. When the segments are tightened upon the drum, they practically become part of it and carry the pulley round with them. This clutch works efficiently, but it is more expensive than other clutches.

At collieries in the South Yorkshire and Derbyshire coal-fields, the Qualter-Hall clutch is used. The clutch shown in Figs. 14, 15, and 16 (Plate XIV.) is capable of transmitting about 100 horsepower. *A* is a cast-iron ring, secured to the driving-wheel, *B*, by plug-fitted bolts. *C* is a boss fixed upon the shaft by keys and provided with circular pins which fit into the holes in the segments, *D*, and cause the segments to revolve with the shaft. A right-and-left-handed screw, with a square thread, connects the two segments at diametrically opposite points. By means of an arrangement of levers and a sliding-sleeve, connected to a hand-wheel-and-screw, these screws may be turned and thus expand the segments against the ring, *A*, causing the wheel to revolve.

There are other varieties of clutch in use, one of which is illustrated in Figs. 17 and 18 (Plate XIV.). In this clutch, the segments are expanded by means of wedges, *A*, instead of screws, this being the only essential difference from the clutch-gear already described.

The Victoria friction-crutch has been described by Mr. L. Dobinson in the *Transactions*.*

With any of these clutches, a pulley 6 feet in diameter fitted with a friction-path about 5 feet by 7 inches will transmit 50 horsepower, with ropes moving at 2 miles an hour. For drives of small power, say 15 horsepower, the Edmiston clutch is used. It consists of a split ring opened or closed in the usual friction-path by a right-and-left-hand screw. At Aldwarke Main colliery, in South Yorkshire, one of these clutches, 2 feet in diameter, with a driving-wheel 4½ feet in diameter is hauling 30 tons per hour up an incline averaging 1 in 4, and 2,250 feet long.

Straining-gear.—After leaving the main driving-pulley, the rope is usually taken to a tightening carriage, consisting of a wheel carried on a travelling frame held taut by a screw or heavy weights. Unless the weights are very massive (thus requiring large excavations for their reception), a jerky motion is put upon the rope often causing it to mount on the drum, consequently at Messrs. John Brown & Company's collieries, weights have been dispensed with, and a wheel tightened by screws is used. This arrangement works excellently, and is applied to nine systems of endless-rope haulages in this group of collieries. In addition to the main tightening gear at the terminus, a small counterbalance is placed on the empty rope, a few feet from the drum.

Ropes.—The ropes, which give the best results, have wire cores, as they do not stretch so much, and compared with hemp-cored ropes of the same strength do not occupy so much room on the drum.

The ropes should be taken down the shaft in boxes strongly bolted to stays in the shaft (Fig. 12, Plate XIII.). The boxes (Fig. 12) are made of pitchpine, 1¾ inches thick, and are 8½ inches square. If the boxes are put in vertically from a centre-line, and carefully fixed they will wear for an almost unlimited period. At Aldwarke Main colliery, endless ropes 1⅛ inches in diameter are taken down a shaft 1,260 feet deep in boxes, 2½ inches square inside, which have never been repaired since they were put in in 1889, and on a recent examination they were found to be coated inside with a mixture of grease and coal-dust which only left a cylindrical path about 1½ inches in diameter in which the ropes travel.

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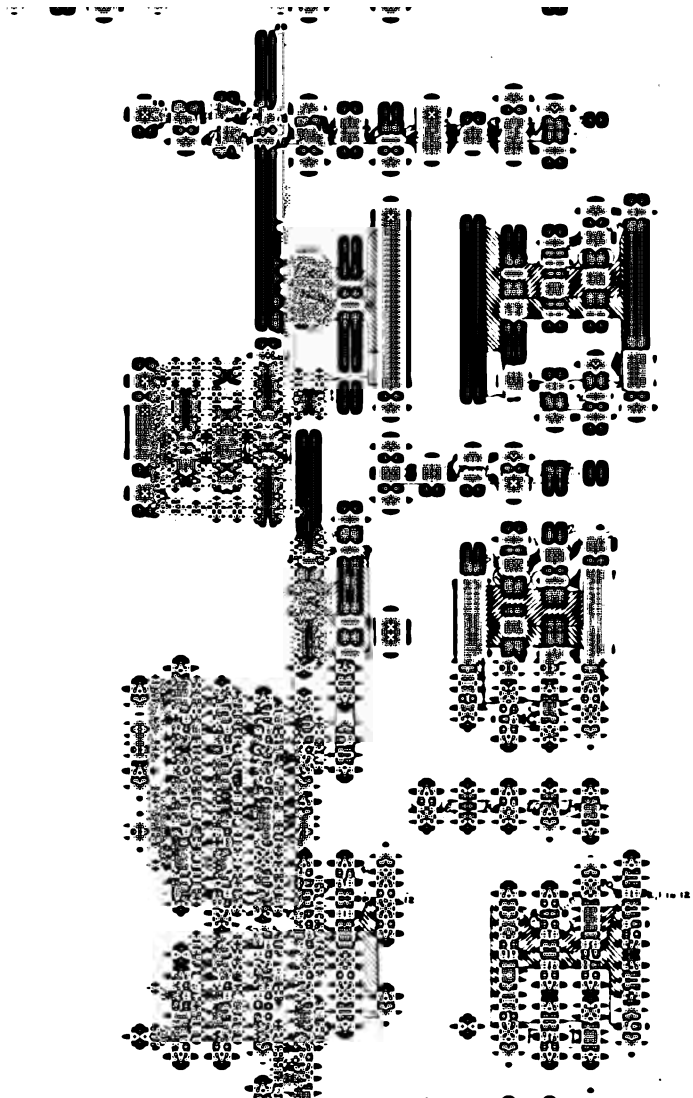
* *Trans. Inst. M.E.*, vol. vi., page 231.

[illegible] ROPES IN SHAFTS.

[illegible]																	
4	2	18	36	—	—	4·8	2	6·6‡	122	1,620	Plough steel, Lang lay.	1⅛	3,600	12	500,000	0·120	Roads are more or less level, except one plane 1,500 feet long, dipping 1 in 20; there is 42,000 feet of haulage-rope at work, driven by this band-rope.
5	—	—	—	—	—	—	1½	10§	110	—	Best improved patent steel.	1⅛	3,750	—	—	0·035	—
6	1 1	20 16	30 30	58	55	5·3	2½	8‖	190	1,200	Best patent steel, wire-core, ordinary lay.	1	3,450	24	460,500	0·049	Engine-planes are practically level.
7	1 1	17 20	30 36	—	—	4·0	4	7¶	70	750	Plough steel, wire-core, and Lang lay.	1⅛	2,100	7	250,000	0·410	This rope works a ram-pump 7 inches in diameter and 3 feet stroke, forcing water to the surface, night and day, and also at week-ends, and a 3-throw pump with 4 inches rams forcing 1,800 feet against 80 feet of head. In addition to coal, 500 tons per week of bind is hauled from a stone-drift, together with 120 tons of water.
8	—	—	—	—	—	—	4	8**	33	882	Improved patent steel, galvanized.	⅞	—	25	—	0·130	—

* Trod, Fig. 2, Plate XIII. † Trod, Fig. 7, Plate XIII. ‡ Trod, Fig. 4, Plate XIII. § Trod, Fig. 5, Plate XIII. ‖ Trod, Fig. 6, Plate XIII. ¶ Trod, Fig. 11, Plate XIII.
** Trod, Fig. 8, Plate XIII.

Vol XVII. Plate XIII.



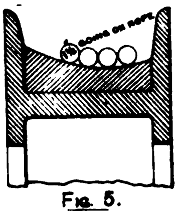

1½
GOING ON ROPE

Fig. 5.

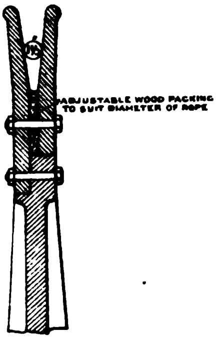

1½
ADJUSTABLE WOOD PACKING TO SUIT DIAMETER OF ROPE

Fig. 8.

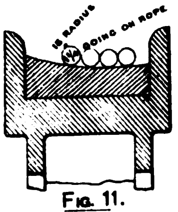
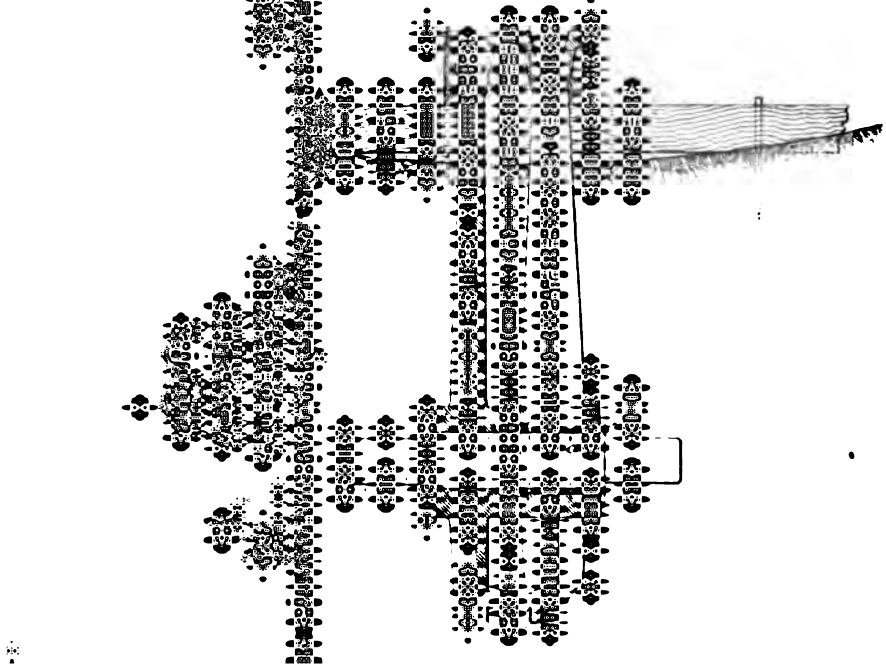
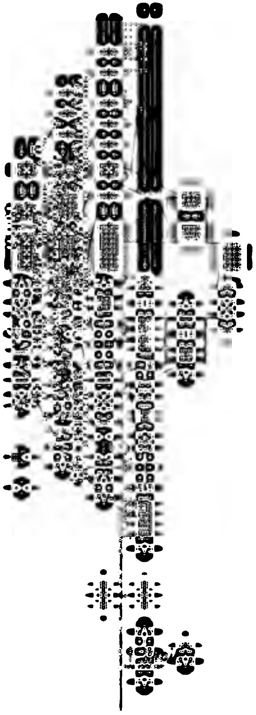

15 RADIUS
1¼
GOING ON ROPE

Fig. 11.



n Shafts.”



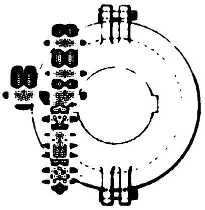
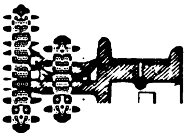


Fig. 16.



In estimating the cost of a band or other haulage-rope, it should be borne in mind that the mere quantity in tons of coal hauled does not give the rope credit for all the work that it performs. The number of tons of water and dirt hauled ought also to be taken into account, the number of times the splice passes over the surge-wheel, and the size of the main driver on the underground gear. For instance, at No. 7 colliery, in Table I., the drum and driving-pulley are each 7 feet in diameter, and the guide-pulleys at the top and bottom of the shaft are each 10 feet in diameter, yet the cost is very much greater than at No. 3 colliery, where four times the horsepower is passed through a rope costing 4s. per cwt. less. This difference is solely due to the fact that No. 3 installation is hauling coal only for 16 hours per day and on 6 days a week, while No. 7 plant is running 20 hours per day for 7 days a week, pumping water and hauling stone.

The PRESIDENT (Mr. J. A. Longden) said that he once had a rather awkward accident owing to a head-rope—the boxes having gradually worn through—bursting through, and became coiled up in an awkward tangle. Clutches always seemed to him to be a difficulty, as they all became slack in the course of time and failed to act. The author spoke of shrouding the pinion-wheel up to the pitch-line, but he (Mr. Longden) thought that when things began to wear, the shrouding became dangerous and threw out the teeth ; but he thought that, while the machinery was new, shrouding would be an advantage. The amount of power which could be transmitted by this method was important, as with far distant working-faces, whence the coal had to be brought uphill, they would want a large amount of power to haul the coals.

Mr. H. HALL (H.M. inspector of mines) said in Lancashire, at any rate, it was the universal practice to use the system of haulage that Mr. Rhodes had described, and so far as his own observation went it worked satisfactorily. He used to be familiar with the main-and-tail-rope system of quick-running ropes, but the slow-running rope seemed to be more satisfactory, as it was less dangerous and there was less wear on the ropes. Rope-boxes were not used, as the strap-rope was kept tight.

Mr. C. C. LEACH (Seghill) said that it would be interesting if Mr. Rhodes could state the actual horse-power transmitted by the 2 feet clutches. Could the writer give any reasons for recommending the use of two-cylindered engines ? Why should an engine with a single cylinder be condemned ?

Mr. **Arnold Lupton** (Leeds) said that he had seen Mr. Fowler's system of quick-running ropes. He had used the Cowlishaw-Walker clutch-gear for some time for driving an electric dynamo. It consisted of a brush on one half of the clutch and a comb on the other half, and when the two halves were placed together, the brush passed over the comb, producing a gradual start without shock.

Mr. **John Gerrard** (H.M. inspector of mines) said that Mr. Rhodes had, in an admirable manner, given those members who wanted to use power under safe conditions the opportunity of obtaining the information that they desired. The wisdom of securely protecting running-ropes had been proved by more than one accident, and in some districts it was required by the Special Rules. In the Burnley district of East Lancashire, the endless chain had been used to transmit power down shafts for many years, but it was going out of general use. At the Rowley colliery, coal was drawn up the shaft by means of a pair of endless chains.

Mr. **G. A. Mitcheson** (Longton) said that he had had some experience in driving secondary haulage by means of a band-rope, and he agreed with Mr. Rhodes that this was an excellent system where they were using endless-rope haulage, but he questioned whether it had any advantage where they had to use the main-rope. In a case coming under his notice, an engine (with 2 cylinders) was erected on the surface to haul, with a main-rope, up a gradient varying from 1 in 10 at the bottom to 1 in 1 at the top. An endless-rope was not used for this incline, as they could not keep a double road (for they had large tubs) at any reasonable expense. To overcome the difficulty of taking the main-rope down the shaft, the haulage-engine on the surface was used to drive a band-rope and a drum at the shaft-bottom, which could be thrown in and out of gear by means of a Fisher-and-Walker clutch. The band-rope ran ordinarily at about 6 miles an hour. Some difficulty was experienced at first, but they enlarged the clutch-gear, and things went fairly well. There was considerable wear-and-tear on the band-rope, and they had to station a man at the haulage-engine on the surface, and to maintain telephone-communication between him and the man at the clutch-gear. The man on the surface varied the speed of the engine, as the speed required varying in the pit. He could tell without a signal when the man at the bottom was letting his run down and when he had thrown it in again. He did not see the necessity for using rope-boxes where they could maintain a taut rope, and would rather be without them. In North Staffordshire, there was a good deal of main-rope haulage, and many accidents occurred from the haulage-rope bursting out of wooden boxes. If boxes were necessary, he had personally come to the conclusion that a 3 inches wrought-iron tube was the cheapest and safest method of enclosing a band-rope. He should be pleased to learn where he could get an efficient governor for an engine with a cylinder 24 inches in diameter by 4 feet stroke, that would keep an engine of that size at a uniform speed, with all the work on and with no work on.

Mr. G. A. Mitchell (Glasgow) said that in Scotland belt-ropes were very largely used: in no case, so far as he knew, were they put in boxes, and he did not see the necessity for it. He was by no means certain that the slow-moving rope was better than the fast-moving one, and it would be satisfactory if they could get a paper on fast-running ropes and discuss the two methods together. The item of expense in belt-ropes was of considerable importance; the ropes did not last for ever, and it was expensive to replace them, but with a fast-moving rope a lighter and less expensive rope could be used. It was a curious fact that in some cases the larger rope did not last as long as a smaller one; he noticed that Mr. Rhodes said he proposed to take off a rope of ⅞ inch in diameter and replace it by one of 1¼ inches; he would like to know the reason for that change. At a colliery with which he was connected there were 6 haulage-planes in 3 different seams, all worked by one belt-rope. The rope used, at first, was 1⅛ inches in diameter and would not last longer than about 9 months. The engine was indicated, and they came to the conclusion that a rope ⅞ inch in diameter ought to be of sufficient strength: it was tried, and found to last from 10 to 15 months, although only costing about one-third the price of the larger rope The rope passed over 14 pulleys, none of which were less than 6 feet in diameter. It may have been that the constant bending of the thick rope caused the breaking of the wires, and consequently that the lighter rope proved better than the thick one.

Mr. R. Holiday (Featherstone) asked what was the greatest power that the writer had known to be transmitted by belt-ropes? He did not see why the supervision of electrical machinery should be costly.

Mr. G. A. Lewis (Derby) said that he was rather surprised to find that Mr. Rhodes had adopted screw straining-gear for tightening the ropes, and he could only say that screws were very likely to destroy the rope in a very short time. At a colliery with which he was connected 12 months ago, endless-ropes were used for haulage, and with screw straining-gear, the rope-splices were drawn in 2 months, but with a tightening carriage, the rope had run about 9 months without showing the slightest sign of wear.

Mr. ARTHUR SOPWITH (Cannock) said, with regard to the straining gear, that the proper place for it was on the empty rope. He had always found, where they could apply it, that a tightening carriage was better than screw-straining gear. The rope should be kept just sufficiently taut, and that could only be done effectively by placing the tightening arrangement close to the driving pulley, where the rope was slack and where the damage was done to the rope.

Mr. M. H. HABERSHON (Sheffield) said that the belt-rope method of transmitting power underground was largely used where the coal was brought up a dip-incline, and the tightening arrangement was placed at the bottom near those places where slack-rope accumulated. He had had some experience with the system, and in the first instance he used a screw-tightening arrangement, which was afterwards replaced by weights. One difficulty found with weights was the space required for the movement of the balance, but by introducing an intermediate pulley between the tightening pulley and the balance, the necessary height-space had been considerably reduced. If they watched the balance-arrangement when a heavy load was on the rope they would see an amount of movement showing that without some appliance of this kind the strain coming suddenly on the rope was very great. The self-adjusting arrangement of tightening frame considerably prolonged the life of the rope.

The PRESIDENT (Mr. J. A. Longden) said that he would not use belt-ropes up a winding shaft, where men were conveyed, unless they were boxed.

Mr. H. WALTERS (Sheffield) wrote that he thought the writer of the paper had scarcely done full justice to the matter. For instance, No. 7 installation, in Table I., shows that the rope has a very short life, with but little explanation. The daily output of 1,500 tons, from a shaft 750 feet deep, and all water and stone was drawn up two planes, by endless ropes, each nearly 1 mile long, with an average gradient of 1 in 12, and some parts even 1 in 9, every bit against the load. The indicated horsepower seems low also, compared with some of the figures given above for No. 7 installation, and this, presumably, will be the power of the engine and not the power transmitted through the gearing at the pit-bottom.

Mr. H. **Rhodes** said that boxes were used in accordance with the requirements of the Special Rules. Wooden boxes were used, clamped with wrought-iron, at intervals of about 1½ feet.

The **President** proposed a vote of thanks to Mr. Rhodes for his paper, and this motion was cordially adopted.

The following paper was read by Mr. **Wm. M. Brewer** on the "Mineral Resources of Vancouver and Adjacent Islands, British Columbia":—

MINERAL RESOURCES OF VANCOUVER AND ADJACENT ISLANDS, BRITISH COLUMBIA.

By WM. M. BREWER, Victoria, B.C.

The more extensively one travels through the province of British Columbia, the more strongly must one become impressed with its immensity, the possibilities of its mineral resources, the inadequate transport facilities as regards waggon-roads and trails, the valuable undeveloped water-power in the vicinity of promising mining fields, the quantity and quality of the timber for use, either in mining, building or for fuel, and the opportunity for development afforded by the numerous navigable waterways which empty into the Pacific Ocean.

In the present paper, the writer proposes to confine himself to that small section of the province which is embraced within the boundaries of Vancouver Island. This island has a length of about 300 miles and an average breadth of probably 50 miles, from the waters of the Straits of Georgia on the east to those of the Straits of Juan de Fuca on the south-west, or the Pacific Ocean on the west and north-west.

In the sounds and inlets along its shores are several excellent deep-water harbours. Many of these penetrate long distances inland, and are navigable for the largest vessels. The most important of these inland waters are:—Saanich Inlet on the south-eastern coast; and Barclay, Clayoquot, Nootka, Kyuquot and Quatsino Sounds on the western. In addition to the sheltered harbours found in these waters are those of Victoria, Esquimalt, Sooke and San Juan on the southern and south-western coasts, as well as several smaller havens along the eastern coast.

The coast-line, except at the entrance to the harbours and inlets, is extremely inhospitable, rocky and dangerous. Innumerable small islands are situated in the inland waters, many of which bear no name except that given by the native Indians. Few of these islands are inhabited, many have never been explored, and all of them are covered with a dense growth of timber and underbrush. The more important of these are as follows:—Texada in the Straits of Georgia; Copper in Barclay Sound; and Stubbs, Mears, Vargas, Indian and Woman Islands in Clayoquot Sound. Usually, the extent of these islands is confined to a few square miles of rocky, wooded and moss-covered hills, sometimes reaching a sufficiently high altitude to be worthy of being classified as mountains. On Texada, Copper and Mears Islands, ore-deposits have been discovered, and more or less development-work performed, especially on Texada. The most extensive, and, in the writer's opinion, most valuable mineral resources on that and Copper islands are the enormous deposits of magnetite, further reference to which will be made later in this paper.

As examples of the extent of the inland waters, there are: The Alberni Canal, which connects with Barclay Sound, with its head some 40 miles from the coast-line; Tofino Inlet and Bedwell Sound, which connect with Clayoquot Sound and head about 20 miles inland; Quatsino Sound also has several inlets emptying into it, the heads of some of which are found nearly 30 miles from the coast. The soundings in the channels of many of these inland waters are marked on the Admiralty Charts as from 15 to 40 fathoms.

The rivers and creeks which empty into these inlets, being mountain streams, are rarely navigable, even for canoes, owing to their swift currents, rapids and falls. The Indians, sometimes, by using poles to push their canoes against the current, ascend some of the larger of the streams for a few miles above their mouths, but in descending they have to exercise every precaution to avoid the rocks in the rapids; even then, such navigation is dangerous.

Although the discovery of Vancouver Island dates back to the seventeenth century, comparatively little was known of it until the discovery of gold on the Fraser River on the mainland in 1856. It was then that prospectors and adventurers from California helped to build up Victoria on the southern coast, and the attention of the world was attracted towards that portion of British North America. Before the discovery of gold, the islands had been practically game-preserves for the benefit of the Hudson Bay Company, which had its forts on the present site of Victoria, and at other points, for trading with the Indians and trappers.

A few years after the Fraser River stampede, placer-gold was discovered on Leach River, about 20 miles from Victoria, and later on Granite and China Creeks, near the head of Alberni Canal, as well as Bear River, which empties into Bedwell Sound. Previous to the discovery of placer-gold, the employees of the Hudson Bay Company had found coal near Port Rupert on the eastern coast. This discovery had led to the immigration from Great Britain of a number of expert coal-miners, some of whom are still alive and residents on the island. Further exploitation resulted in the discovery of thicker seams of coal to the south on the same coast, at Union, Nanaimo and Wellington, where extensive collieries were established, and have since furnished a very large proportion of the coal consumed along the Pacific coast. Coke-ovens were introduced later, and the following table taken from the *Report* of the Minister of Mines for the year ending December 31st, 1898, demonstrates to how great an extent this industry has developed :—

PRODUCTION OF COAL.

Years.	Tons.	Values.	Years.	Tons.	Values.
		Dollars.			Dollars.
1836-52	10,000	40,000	1879	232,390	697,170
1852-59	25,398	101,592	1880	272,362	817,086
1859	1,989	7,956	1881	229,514	688,542
1860	14,247	56,988	1882	288,572	865,716
1861	13,774	55,096	1883	214,353	643,059
1862	18,118	72,472	1884	393,866	1,181,598
1863	21,345	85,380	1885	333,024	999,072
1864	28,632	114,528	1886	335,192	1,005,576
1865	32,819	131,276	1887	434,055	1,302,165
1866	25,115	100,460	1888	481,667	1,445,001
1867	31,239	124,956	1889	568,249	1,704,747
1868	44,005	176,020	1890	685,345	2,056,035
1869	35,802	143,208	1891	1,009,176	3,027,528
1870	29,843	119,372	1892	836,802	2,510,406
1871-2-3	148,459	593,836	1893	976,768	2,930,304
1874	81,061	243,183	1894	993,418	2,980,254
1875	97,644	292,932	1895	944,683	2,834,049
1876	140,185	420,555	1896	896,222	2,688,666
1877	139,692	419,076	1897	910,170	2,730,510
1878	190,848	572,544	1898	1,135,865	3,407,595

PRODUCTION OF COKE.

Years.	Tons.	Values. Dollars.
1896	500	—
1897	19,154	—
1898	35,000*	175,000*

* Estimated.

It was not until about 1892 or 1893 that prospecting was commenced for gold-bearing quartz, and still later for sulphide-ores carrying gold, silver and copper. In fact, at the present day, lode-mining is in its infancy on the island, and the results now being obtained by placer-miners near the head of Bear River demonstrate that the pioneers did not work out all the placer-ground.

The *Reports* published by the Geological Survey of the Dominion of Canada only treat of the geology along the shores of Vancouver Island. The reason for this is that the penetration of the interior has been most difficult, owing to the extremely heavy growth of timber, underbrush, and especially the thickets of *sallal* and *devil's clubs*, which grow most luxuriantly in the valleys. Consequently, but little of the geological conditions in the interior is known. Few prospectors, even, have crossed the island, except the stretch from Nanaimo coal-fields to the head of the Alberni Canal where it is traversed by a stage road.

Volcanic disturbances have undoubtedly been frequent, and comparatively recent, because the limestones occurring throughout the western portion and semi-crystalline slates in the southern portion of the island are apparently older than the igneous rocks, which occur as intrusive dykes. The dykes usually form the mountain-peaks, not only in the southern, but also in the western portion of the island, so far as the writer's observations have extended. Sandstones, and the Coal-measures, he learns, prevail through most of the eastern, north-eastern and northern portions. These, as well as the mountain-ranges, trend north-westward. Along the south-western coast, near San Juan Harbour, a narrow belt of sandstone with Coal-measures also occurs, dipping into the Straits of San Juan de Fuca. The interior of the island, so far as the writer can learn from either his own observations or reliable information, is made up principally of limestone, often beautifully crystalline, with intrusive dykes of diorite, diabase, granite and porphyrite.

The discoveries of ore-bodies in the Kootenays, capped by gossan, and unaltered iron-ore outcrops, caused prospectors to turn their attention to other sections of British Columbia, and served as an incentive to many to explore portions of Vancouver and the adjacent islands, where several deposits of magnetic iron-ore were known to occur. Some of these, especially on Texada Island, situated between the mainland and the northern portion of Vancouver Island, in the Straits of Georgia, and on Copper Island, near the mouth of Barclay Sound, had already attracted the attention of capitalists. The first-mentioned had been acquired by the Union Iron-works Company of San Francisco, some ore being mined and manufactured into pig in the blast-furnaces owned by that company at Irondale, near Port Townsend, in the State of Washington. The ore is a very pure magnetite, carrying about 62 per cent. of metallic iron, traces of phosphorus, and a small percentage of silica. It is claimed that the iron-work on the vessels built at the Union Iron-works for the United States Navy was manufactured from pig iron made from the ore mined on Texada Island, and that its superior in quality is very hard to find.

Underlying the deposits of magnetite, sulphide-ores were found on Texada Island, carrying from 4 per cent. of copper up to, it is claimed, 25 per cent., besides gold-values varying from traces to appreciable quantities.

Systematic exploitation of these occurrences of copper-pyrites is now being made to determine the permanency and extent of the ore-bodies. The country-rock on the western side of the mountain of magnetite is of igneous origin, while on the eastern side it is limestone. Whether as depth is attained the body of ore will be found between regularly well-defined walls, or whether it occupies a basin or trough in the limestone, and does not maintain continuity to any appreciable depth can only be determined by the result of the work now being carried on. The mass of iron-ore forms a sugar-loaf-shaped mountain, higher than any in its near vicinity, and extends also along the summit of a ridge or hog-back for some distance to the south-east of the main deposit.

With the exception of those portions of Vancouver Island adjacent to the Alberni Canal, and Leach River, which empties into Sooke Harbour, no prospecting for quartz had been done earlier than 1892; but since then discoveries of the occurrence of auriferous copper ores have been made on Saanich peninsula at the southern end of the island, as well as in the mountains along the coast from San Juan Harbour to Quatsino Sound. At the present day, these discoveries can only be classed as "prospects," although shipments of ore have been made to smelters in the State of Washington, U.S.A. A few occurrences of galena in a quartz-gangue have been recently reported in the vicinity of Cowichan Lake, in the eastern portion of the island, near the line of the Esquimalt and Nanaimo railway.

The earliest discoveries of gold-bearing quartz-veins were made in a belt of semi-crystalline slate which apparently extends from the south-eastern portion near Saanich peninsula, with its trend at about 20 degrees north of west, across Leach River and to the west coast, probably near San Juan Harbour. So far as at present known to the writer, another belt of this slate, which apparently traverses the island, having a north-westerly line of strike, is the north-eastern border of the crystalline area of the island. To the south and west there are apparently several mineral zones, while to the north and east of the crystalline rocks occur the Coal-measures and sandstones. This belt lies north of the first-mentioned.

So far as the writer's observations have extended, he is inclined to the opinion that the ore-bodies occurring in these zones cannot be traced without break for any very considerable distance, and even where the outcrops are very persistent, the ore is found in lenticular chutes. The problem of permanency in deep workings has yet to be solved, as well as the maintenance of values. The iron-capping itself is often deceptive, especially at the contact between limestone and igneous rocks.

Most of the ore-bodies, so far discovered on the west coast, occur at the line of contact between crystalline limestone and diorite or porphyrite, but fissures in the igneous dykes are often found with their lines of strike almost due north, and the dip usually vertical or nearly so, rarely pitching at a lower angle than 75 degrees. Where these fissures occur, one wall only is well defined, usually the foot-wall. Indeed, it is a rare occurrence in British Columbia to find two well-defined walls, with "gouge" separating each from the ore-body. It is nearly an universal rule that the ore occurs in more or less compact masses, as impregnations in the country-rock on the hanging-wall side. In thickness, these ore-bodies vary from a few inches to several feet, consequently a thorough system of cross-cutting is necessary to determine their extent. Usually, the highest-grade ore occurs next to the foot-wall, but no hard-and-fast rule can be laid down.

It is too early in the history of lode-mining on Vancouver Island to warrant any expression of opinion as to its future prospects. To the writer's knowledge, none of the ore-bodies have been opened to a depth of more than 200 feet. But during the present season more systematic development is being carried on than ever before, and, undoubtedly, ere the close of the century the permanency of many promising "prospects" will have been determined.

So far as outcrops are concerned, and surface-indications generally, there is probably no mining country in the world where they are of greater extent, or carry sulphide-ores of higher grade, so near the surface of the ground. Immediately underlying the gossan and magnetite outcrops, pyrrhotite, chalcopyrite and iron-pyrites carrying high-grade values occur so close to the surface, that in one instance near the head of Bedwell Sound (which came under the writer's notice) between 30 and 40 tons of ore carrying an average of 15 per cent. of copper and traces of gold to the ton, were taken from a prospect-hole 10 feet deep and 6 feet square at the mouth. In another instance, a drift run about 20 feet along the contact of a diorite-dyke and crystalline limestone was in solid ore averaging 8 per cent. of copper, but at 20 feet under cover the limestone was "frozen" to the diorite and cut off the ore-body: however, a few feet farther in, the writer is informed, some ore has again been encountered. Work has now been suspended at that point, until another year's assessment becomes due. At still another prospect, a body of bornite in baryta-gangue cropped out at the surface. A shallow cross-cut exposed a thickness of 10 feet, and stripping along the line of strike determined the continuity for over 100 feet. A syndicate is now developing this prospect, to determine its continuity with depth.

As an example that the iron capping is sometimes deceptive, the writer saw one prospect where a cross-cut tunnel had been run 60 feet to intersect an ore-body supposed to occur under a heavy outcrop, at a depth of about 40 feet. No ore was found, although breccia indicating a fault and crushing movement was encountered. The course of the tunnel was changed to follow along the strike of this, and at a distance of about 70 feet farther, a chute of ore was exposed. Such an illustration proves the advisability of staying with an ore-body when it is exposed, either at the outcrop or in workings, rather than taking chances of cross-cutting it at some depth, when an outcrop only has been found.

In the ore-bodies occurring at the contact between crystalline limestone and igneous rocks the gangue is usually limestone, and often in such quantities as to depreciate the grade of the ore very considerably, at the same time rendering it a very desirable ore for smelting, and, consequently reducing the cost of treatment. The solid sulphide-ores of copper carry so high a percentage of iron and sulphur as to make them very popular with smelter-managers.

Some years ago, a good deal of excitement was occasioned by the reported discoveries of high-grade free-milling auriferous-quartz bodies on Vancouver Island, near the head of Alberni Canal. The cost of transporting machinery into the interior, lack of systematic development, and various other causes have operated against the thorough exploitation of such ore-bodies, wherefore at the present time no stamp-mills are in active operation. Most of the prospects showing this character of ore are still owned by the original locators, who are prospecting without capital. They usually ask such high prices for their property that capitalists, who might have been favourably disposed towards acquiring such, have been frightened away from the field. In many of these quartz-veins, high-grade outcrops have been found, but insufficient systematic development makes it impossible to form any reliable opinion as to the extent or permanency of the free-milling ore. It is probable that, as depth is attained, if continuity be determined, the character of the ore will change to refractory, and concentration followed by either chlorination or the cyanide process will become necessary to extract good values.

The possibilities of Vancouver Island as a mineral-producer are, judging from surface-indications, very promising. The fact that the climate is so temperate as to admit of continuous working during the winter months, and of prospecting during about 7 months of the year should cause it to be very attractive to both operators and prospectors. The low cost of water-transport, the number of deep-water harbours and wharf-sites in the bays and sounds (especially on the western coast), are among its attractive features, as well as the ample supply of timber and fresh-water for machinery, smelting and concentrating.

The lack of waggon-roads and good trails from the coast to the interior will gradually become remedied, because each year the prospectors are penetrating farther into the island, and the provincial government is showing a disposition to build the necessary bridges and roadways, so as to encourage the development of the mineral resources.

The heavy rainfall during certain seasons of the year is of course, to some extent, detrimental to prospecting work, but the greatest difficulty in the way is the transport of supplies, which at present have to be carried into the interior on the backs of prospectors and professional packers. Even pack-mules and horses have not yet been generally introduced into the island, because there are but few trails along which they can travel. Very little grass grows on the mountains, but there is a variety of moss which grows often several inches thick, and entirely covers the rock-formations.

The PRESIDENT moved a vote of thanks to Mr. Brewer for his valuable paper, and the motion was cordially approved.

MINING FOR GOLD IN THE AURIFEROUS GRAVELS OF CALIFORNIA, U.S.A.

By GEORGE KENT RADFORD, M.Inst.C.E.

The discovery of gold in surface-deposits in California dates from January 19th, 1848, when James W. Marshall found it at Sutter Mill, Coloma, El Dorado County. Subsequently Redding at the head of the Sacramento Valley and Bidwell on the Feather river commenced working it.

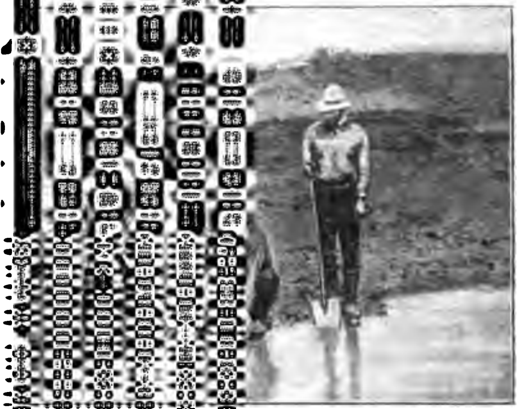
In 1849, the *placers* of Trinity and Mariposa, and in 1850 Klamath and Scott Valley were discovered. Since then, placer-mining has been extended over nearly the entire State of California, and at the present time is carried on more or less extensively in the counties of Butte, Del Norte, El Dorado, Humboldt, Los Angeles, Nevada, Plumas, Sierra, Siskyou, Sutter, Shasta and Trinity.

Various theories have been set forth as to the genesis of these auriferous gravel-beds ; and geologists, miners, etc., differ in their ideas as to the primary causes. The marine theory ascribes the formation of the gravel-deposits to the action of the sea. The glacial theory to ice; and the fluviatile or deep-river theory to ancient rivers, depositing gravels in valley-channels, afterwards covered up more or less by alluvions, lava, etc.

The fluviatile theory is probably more generally accepted at the present time, but whichever may be the true one, there is little doubt that the sources of the gold have been the quartz and other matrices in the mountain-ridges which have been eroded by flowing water in former geological periods.

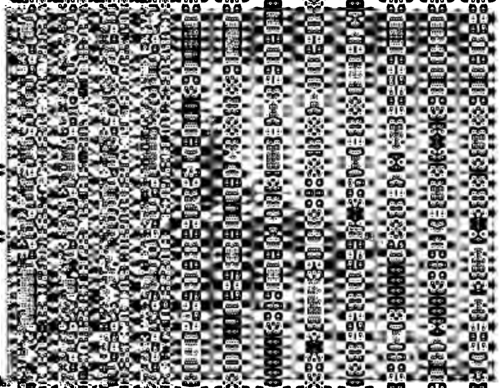
The gravel-deposits occur in a great variety of textures, ranging from very fine pipe-clay, through sands and gravels, to rolled pebbles and boulders, sometimes weighing several tons. Miners have an idea that the colour of the gravel is indicative of its auriferous character, and that the blue gravel is especially rich in gold. However that may be true in certain localities, it does not hold good for all. Gravel is generally richer nearer the bed-rock than in the upper portion of the deposits, ds its way thither, and may be bluer, owing to

other countries, where rivers, etc., the primary



USING THE BATEA OR PAN.

hen worked in a pool of nd shaking process, until the fine particles of gold are left at the bottom of the pan (Fig. 1).



Rocker-and-cradle.—This method is improved on by the rocker-and-cradle, still in use in prospecting, consisting of a box with sides sloped like a cradle, on rockers; the upper end is a removable hopper with a it is a canvas apron upon Fig. 2).

ovement, which is either gh formed of planks, with cross-pieces or riffles on the bottom. A dam is constructed across some convenient stream, and the impounded water led by flumes or pipes to the head of the sluice. The excavated gravel is dumped into the sluice, dissolved and carried down by the water, the particles of gold, being the heaviest, naturally sink to the bottom and are arrested by the riffles. The riffles are treated with quicksilver, which attracts the gold and forms an amalgam.

After a certain period or run, the water-and-gravel supply is stopped and a clean-up occurs. The riffles are gradually removed and the fine sand and amalgam are scooped up into buckets. The contents of the buckets are then panned or washed in a vat, and the clean amalgam separated. The amalgam is retorted, the quicksilver going off in the fumes, leaving the gold in the retort, which is afterwards remelted and refined and run into a mould. The fumes are condensed in water, and the quicksilver thereby recovered.

Hydraulic Mining.—Practically the same processes are employed in the most advanced form of hydraulic mining. Instead of the small sluice fed by hand, with its little dam and water-supply, there are in some cases impounding or storage-reservoirs among the hills, miles of ditches from thence to the immediate neighbourhood of the mine, crossing valleys by means of iron or steel-pipe syphons, or by flumes or aqueducts, with distributing reservoirs and penstocks. Iron or steel pipes run thence into the mine, furnished at their termination with monitors or giants, from which the water issues with great velocity and force, impinging on the gravel-banks, breaking them down, and washing the material into the sluices, down which it flows, depositing the gold on the sluice-bottom, and discharging the *débris* into a channel at its end.

In some cases, where the law compels the miner to do so, the *débris* is elevated from the end of the sluice and deposited behind a dam, where the *slickens* or mud settles.

Derricks or other equivalents are used to remove such rocks and boulders as may be too large to pass down the sluice.

When the lie of the ground does not provide proper drainage, the water and gravel are lifted by machinery from the pit and discharged at a higher level, as may be convenient.

Gravel-mining is also carried on in the beds of rivers, which may be favourably situated for so doing, by wing or whole dams, or by tunnelling through the narrow neck, and diverting the stream, so as to expose its dry bed, and also by dredging the sand and gravel which form a bar, and collecting the gold therein.

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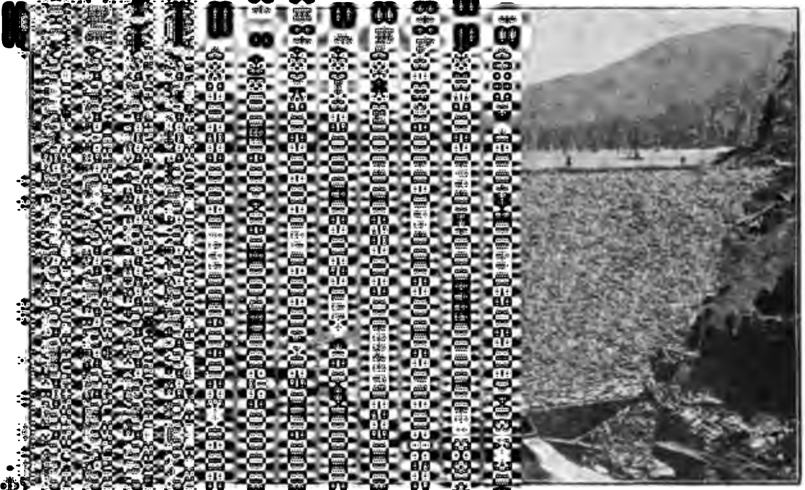

MAIN DAM.

ic feet capacity. Where
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and inclinations or grades,
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d Gravel Mining Company is
nd 98 feet above the bed of
e thickness, at the bottom,
feet of stone. The water is
5 miles. The average rain-

The miner's inch of water is a quantity, which varies in almost every district in California, although the legal inch is a flow of 1,728 cubic feet in 24 hours.

The North Bloomfield inch is calculated on the discharge through an opening 50 inches long and 2 inches wide, through a plank 3 inches thick (outer inch chamfered) with a head of water 7 inches above the centre of the opening, and is considered to be 2260·8 cubic feet in 24 hours; the coefficient of discharge being 61·6 per cent. The module employed to gauge the water at the mine is an aperture 12 inches high, 12¾ inches wide, through a 1½ inches plank, with a head of 6 inches above the top of discharge, which is considered to be 200 miner's inches.

The Smartsville inch is calculated on a discharge through a 4 inches orifice with a head of 7 inches above the opening or 9 inches above the centre, and is taken as 2534·4 cubic feet in 24 hours.

The miner's inch of the Park Canal and Mining Company in El Dorado County is taken at 1977·6 cubic feet in 24 hours.

The South Yuba Canal Company's inch is the discharge through a 2 inches aperture over a 1½ inches plank, with a head of 6 inches above the centre of the orifice.

A series of experiments made at La Grange, Stanislaus County, California, with an opening 50 inches long, 2 inches wide, through a 3 inches plank, head 7 inches above centre of opening gave the inch as 2159·1 cubic feet in 24 hours; the coefficient of efflux being 59·05 per cent.

The North Bloomfield ditches have a carrying capacity of 3,200 inches, and are 8 feet 8 inches wide at the water-line, 5 feet on the bottom, and 3 feet 6 inches deep, grade 12 to 16 feet per mile, 55 miles long, and the reported cost is £93,341 ($466,707). The Milton Company's ditches are 84 miles long, grades 12 to 32 feet per mile, 7 feet 8 inches wide at the water-line, 4 feet on the bottom, 3 feet 6 inches deep, capacity of 3,000 inches, and the reported cost £92,600 ($462,998). The Eureka Lake main ditch is 18 miles long, with a capacity of 2,500 inches, and the cost £51,200 ($256,000); and the San Juan ditches are 45 miles long, capacity 1,300 inches, and the cost £58,600 ($292,992).

These ditches are laid out on regular grades, following surface-inclinations, and are necessarily very sinuous in their course, with sharp and abrupt turns at the heads of valleys. Cut into the sloping sides of the hills, they collect all the water which falls above the ditch-line, and this way-water is sometimes sufficient to supply the wants of the mine for several months, without drawing on the storage-reservoir, if such exists (Fig. 4).

Syphons.—When the ditch-line has to cross a valley, an inverted syphon-pipe, or an aqueduct-flume, is used to carry the water. Some syphons are of considerable length and of great depth of valley. Among the most noted syphons are those described in Table I.

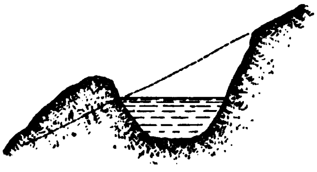


FIG. 4.—SECTION OF DITCH ON SIDE-LYING GROUND.

TABLE I.—INVERTED SYPHON-PIPES.

Locality.	Length.	Pressure.		Diameter of Pipe.	Thickness of Iron.		Tensile Strain per Square Inch of Metal without Allowance for Rivet-holes.
	Feet.	Feet.	Pounds per Sq. In.	Inches.	B.W.G.	Inches.	Pounds.
Cherokce	—	887	384	30	00	0·375	15,360
Humbug Cañon ...	1,140	118	51	27	16	0·065	10,600
Texas Creek ...	4,438	760	329	17	8	0·165	16,952
Virginia City Water Company ...	37,100	1,720	750	11½	0	0·324	13,310

Flumes.—Aqueduct-flumes are constructed of either a square or V section, of plank sides and bottom, sills, side-posts, braces, capsills, gang-planks, etc., and carried on trestles, sometimes 80 feet and more in height, or cut into the mountain side (Figs. 5, 6, 7 and 8).

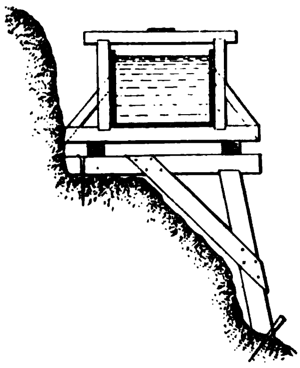


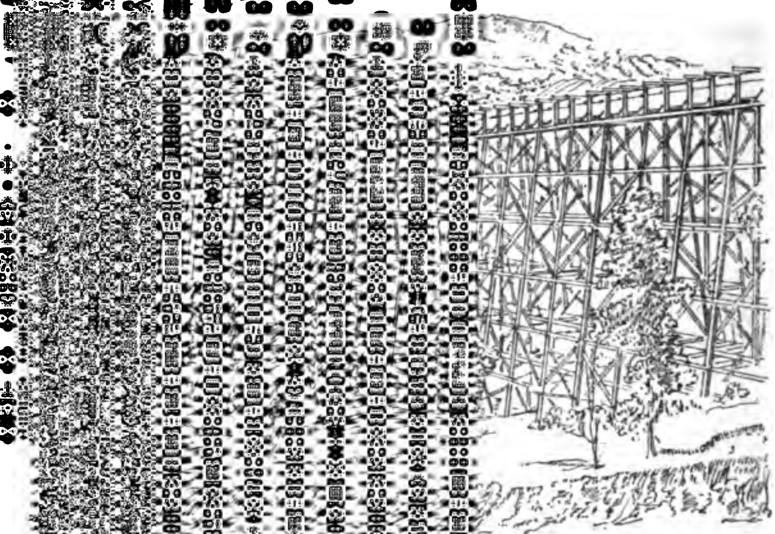
FIG. 5.—SECTION OF FLUME, ON SIDE-LYING GROUND.

The Miocene Mining Company has constructed a bracket-flume, which is carried on T rail brackets, one end being fixed in a hole drilled in the vertical face of the rock, and the upper end suspended by a rod from the rock. The flume is 4 feet wide, 3 feet deep, and has a capacity of 3,000 inches (Fig. 9).

Waste-gates are provided at convenient points in the ditch or flume-line, to discharge surplus water, and to empty the ditch or flume when required.

IFORNIA.

Company, near Weaverville,
ucted a flume with a pipe-
ts Fork to a junction with
William H. Radford being
and the author consulting
onsists of a diverting dam
of timber flumes on a grade
hich proceeds a 30 inches
s the valley of the Stuarts
he lowest point, below the



Y'S FLUME TRESTLE, MORRIS
LIFORNIA.

reen the entry and delivery
e more of timber flume in a
about 9,000 feet in length,
flume to the junction with

ttom and 6 feet wide at the
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of 56,000 to 62,000 pounds
in thickness from No. 14
g to the pressure, and regu-

xceeding 20,000 pounds
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to 28 feet 6 inches for
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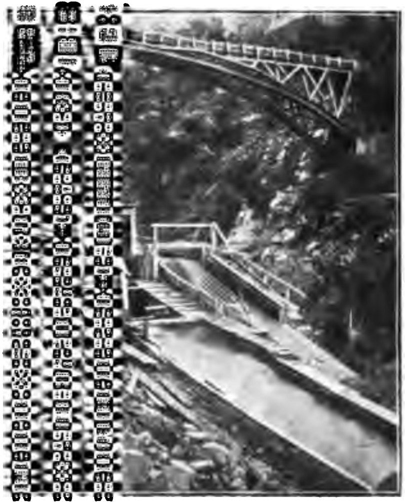

—View showing Method of
a Flume across a Cañon by
Bridge; also a Grizzley
oving large Boulders.
space prevented the In-
n of an Under-current
oint.

ss the Stuarts Fork on
n (Fig. 10). The pipe
pipe and back filled over

flat of the valley, thence
team hoist and wire-cable,
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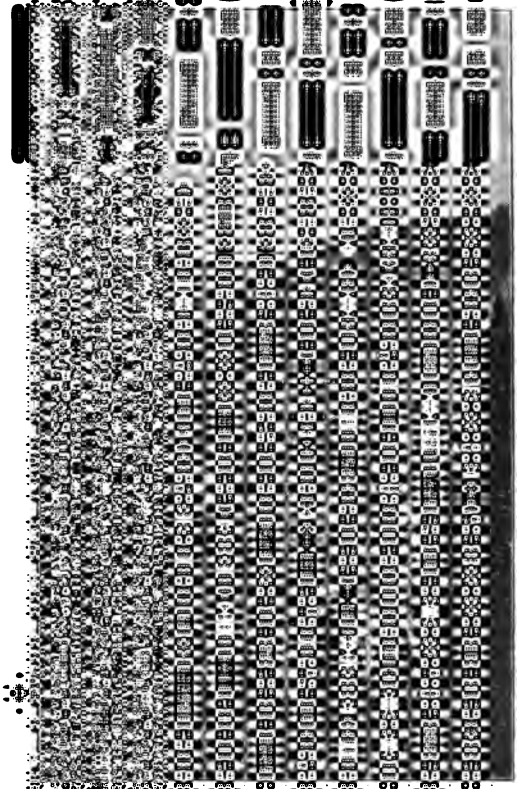
er head, their diameters are less, so that this pipe-line ation of a valley-crossing in

ing-reservoir is used for itch to the demand of the ine as convenient so as to



obtain sufficient head, and to command all the mine ground. Its size is necessarily determined by the circumstances of each particular case, as to site, supply and demand.

It is furnished with *modules* or measuring-gates at the termination of the ditch, so that the quantity of incoming water can be ascertained. The reservoir-keeper regulates the water-supply to the monitors by means of the valve or gate on the outlet-pipe. The distributing - reservoir is usually located at too great a distance from the first workings of a mine to make it convenient to lay the supply - pipes directly is constructed to carry the positions for working the Weaverville, Trinity County, ably well situated gravel-mine

to a penstock or sand-
erally about 12 feet by
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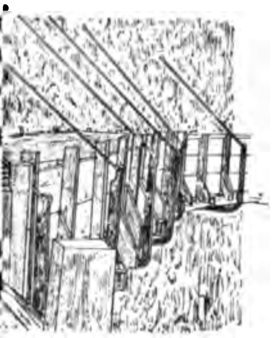
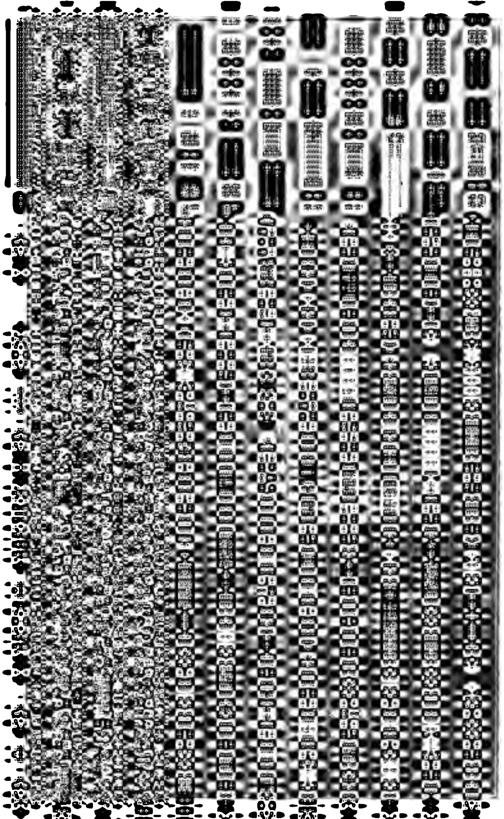


ION OF THE MIOCENE MINING
Y'S BRACKET-FLUME.

Birmingham wire-gauge.
ich may be considered as

Thickness of Pipe.		Maximum Tensile Strain of Metal without Allowance for Rivet-holes.
B.W.G.	Inch.	Pounds per Square Inch.
14	0·083	10,165
10	0·134	15,276
14	0 083	12,520
14 16	0·083 0·065	5,862
12	0·109	15,140
12	0·109	14,600
10	0·134	16,720
10	0·134	16,000
12	0·109	13,403
18	0·049	14,120
18	0·049	9,753
7	0·187	3,700
11	0·125	5,542
14 12	0·083 0·109	5,161
18	0·049	12,725
11	0·120	19,000
14	0·083	23,476

feet in width and of a length
meter, allowing for a lap-joint
ngitudinal seams are riveted,
r, with single riveting in the
in length, which is generally
to prevent corrosion. These lengths are then laid together, with stove-pipe joints without rivets, but secured by an external band and tightening-screw arrangement (Fig. 15).

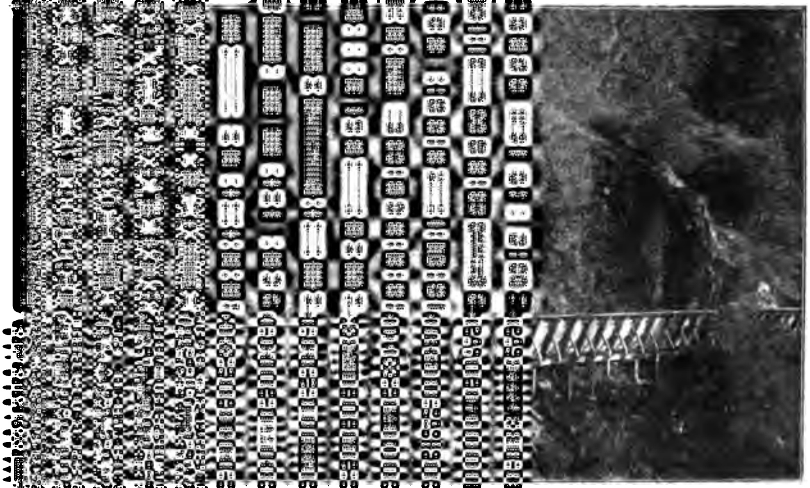


The iron or steel is generally punched and formed in the shop, packed one sheet inside the other for convenience and economy in carriage, and riveted at the mine; but in some cases it is made up in the 17 feet lengths and shipped to the mine, advantage being taken of packing the smaller inside the larger sizes.

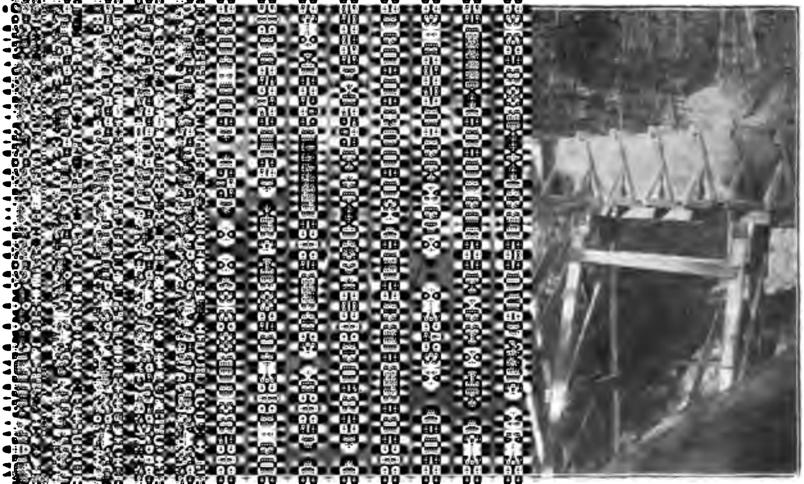
Air-valves of a simple construction are provided at all vertical bends in the pipe-line, and more or less according to the judgment of the pipe-layer, to allow of the air escaping as the pipes are being filled with water (Figs. 16, 17 and 18).
as possible, and where bends
d weighting, and generally
c., to preserve regularity of

with more or less judgment,
ground as possible, and to

[illegible] the mine, or may be pro- [illegible] and branches of smaller [illegible] us at the end, variously



[illegible] nge Hydraulic [illegible]



[illegible] Grange Hydraulic [illegible]

[illegible] ts of a cast-iron box, with [illegible] ing on a ball-and-socket [illegible] 9 feet in length riveted [illegible] om 2 to 8 inches in diameter

[illegible] r, consisting of a tapering [illegible] operated by the *piper* or

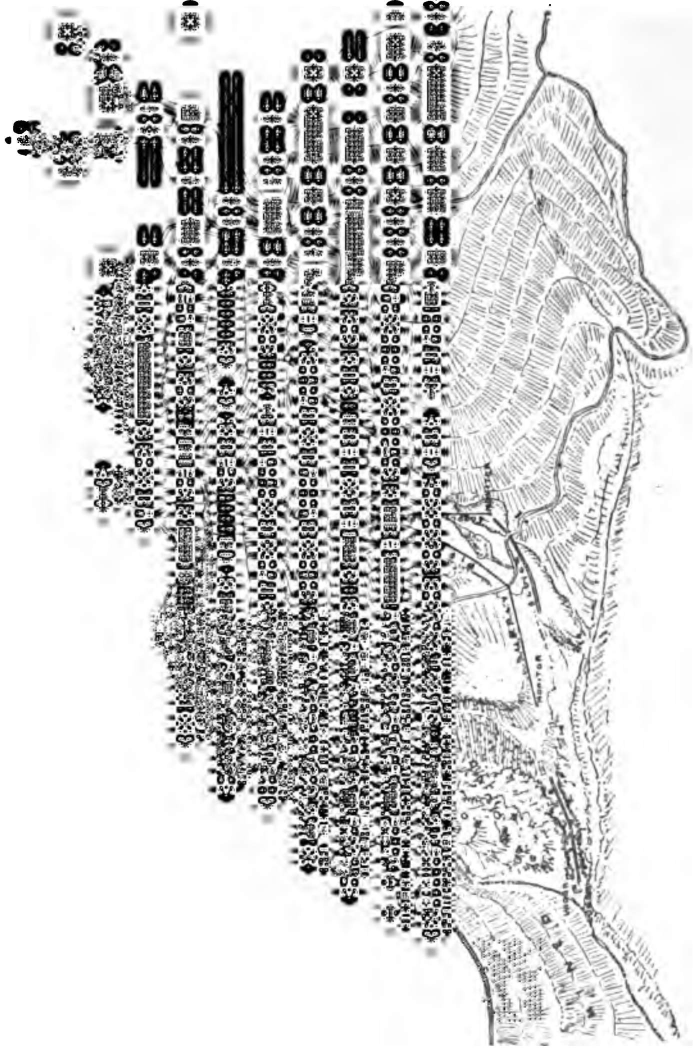


FIG. 13.—PLAN OF LA GRANGE GRAVEL-MINE, WEAVERVILLE, TRINITY COUNTY, CALIFORNIA.

[illegible] ower the nozzle as he pleases, [illegible] principle as the rudder of a [illegible] ozzle and the disintegrating [illegible] judgment in each particular case, governed by the head and quantity of water and composition of the gravel. One size of jet is the best suited for "cutting" the bank, and another for washing it down (Figs. 22, 23 and 24).

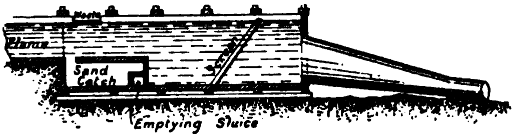


Fig. 14.—Section of Penstock.

The monitor is placed as near as possible to the face of the gravel-bank, so as to secure the greatest effect of the water-jet, governed by consideration of safety to men and apparatus, from "caving" and sliding of the bank; the higher the bank the greater is the distance required. Very high banks are sometimes worked in benches. If the gravel is very tenacious and much cemented together, it may be necessary to break it down by blasting, and so enable the water to act upon it more advantageously. This is done in the ordinary way, by drifting in from the face and running a cross-cut parallel to it, firing by electricity or ordinary fuze, as advisable.

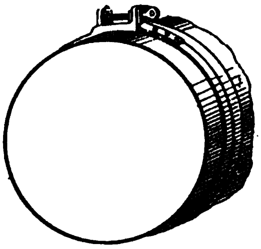


Fig. 15.—Joint Band.

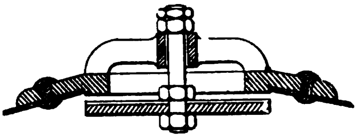


Fig. 16.—Section of Air-valve.

Sluices.—The gravel, being disintegrated and carried down by the jet of water, is generally conveyed by a rough channel formed in the bed-rock, to the sluice, the head of which is kept at a safe working distance from the bank-face. The sluice consists of a trough or box, formed of plank bottom and sides, joints covered with battens, sills, posts and angle-braces, and is usually made in 12 feet lengths or boxes (Fig. 25).

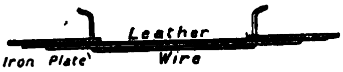


Fig. 17.—Section of Air-valve.

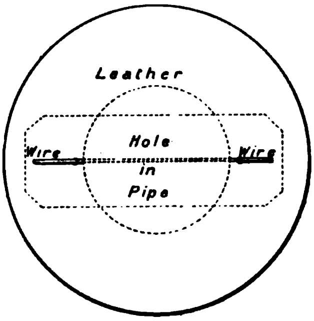
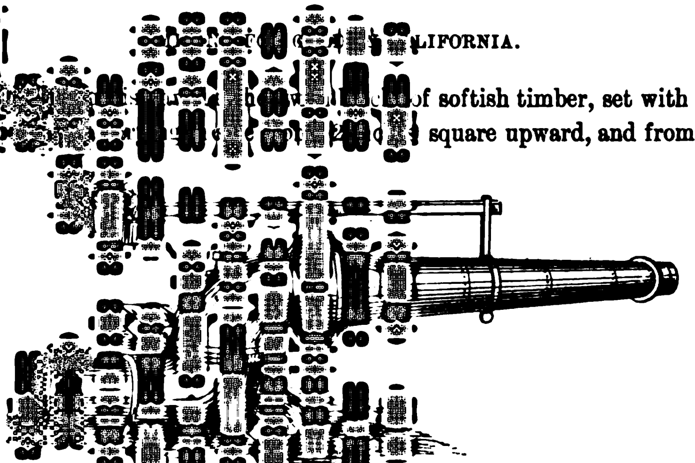
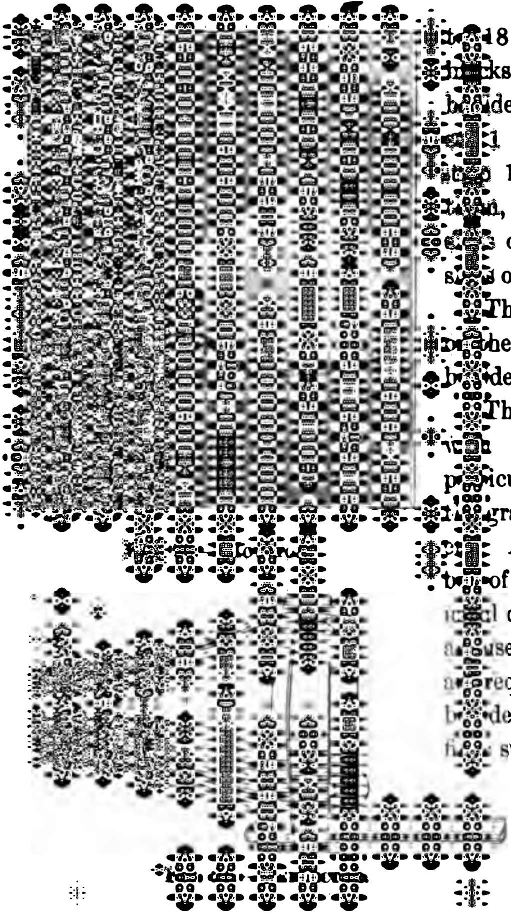


Fig. 18.—Plan of Air-valve.

of softish timber, set with the square upward, and from 10



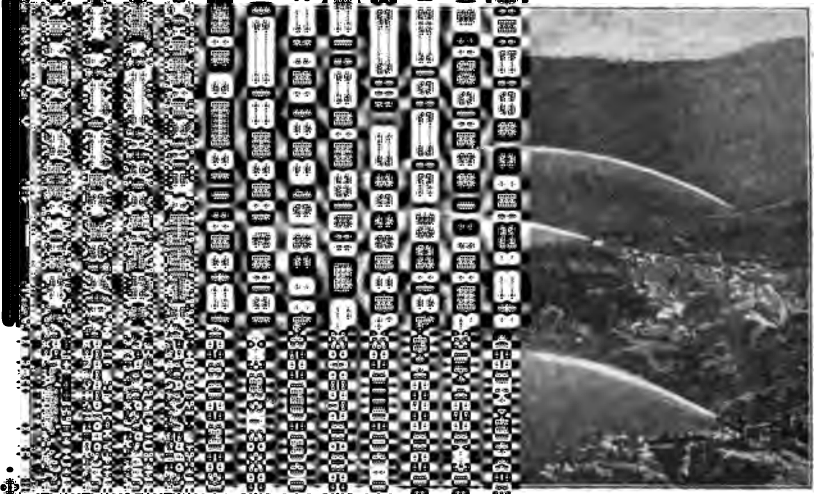
ING ATTACHMENT.



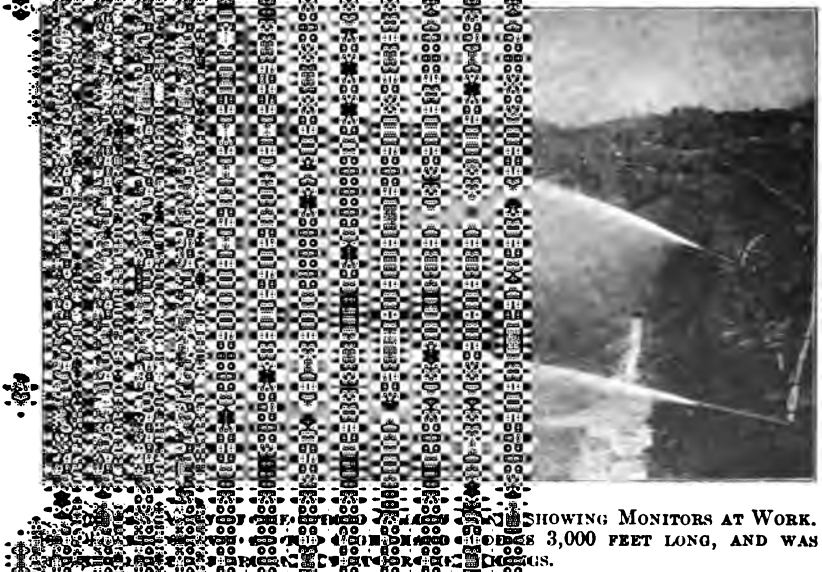
18 inches in depth, or with blocks of rough stone, generally boulders. The wooden blocks are 1 inch apart, with a parting 1 inch by 4 inches between , thus acting as riffles. The of the sluice are lined with of wood about 3 inches thick. The sluice is either set directly the bed-rock, or on trestling or boulders, as most convenient.

The grade or inclination varies the circumstances of the particular mine, composition of gravel, grade of the bed-rock, A grade of 6 inches to the of 12 feet is perhaps the most one, but 4, 6, 8 to 12 inches used as required. Steep grades required for heavy gravel with boulders, and light grades with stuff.

The width and depth vary with the demands of the mine as to the quantity of gravel and [illegible] wide, and 2 to 3 feet deep. [illegible] carry off all the material [illegible]



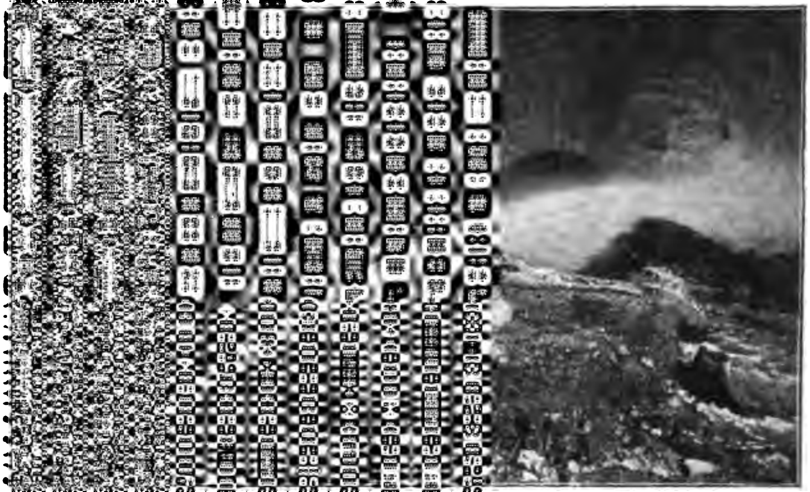
[illegible] LD MINE, SHOWING [illegible]



[illegible] SHOWING MONITORS AT WORK. [illegible] 3,000 FEET LONG, AND WAS [illegible] GS.

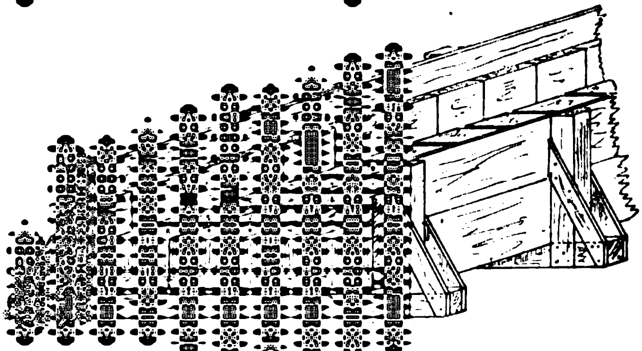
[illegible] hich attracts the suspended [illegible] ally a certain percentage of

, an additional apparatus, delivery-end thereof. grating of iron bars, laid as erstices of which the water



MONITOR PLAYING 500 MINER'S OF 360 FEET.

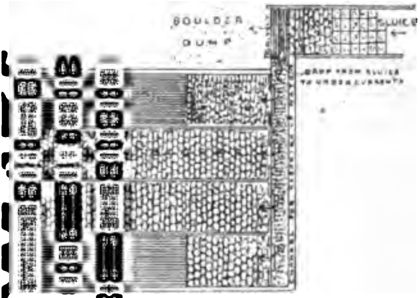
cles and boulders pass on to e particles falling through o the sluice, and pass along



UICE.

ovided with entry-gates, so d. The under-currents are

, piping goes on day and
fore required. These are
l lamps with reflectors, or



—Plan of Under-current.

, without hindrance. The
re is no free dump, and it
the intervening rim of the
n access to some ravine and

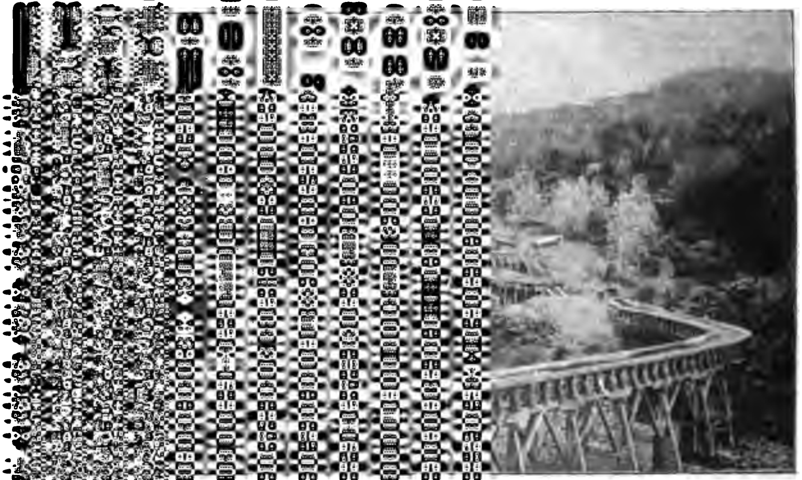
nnels.—This is the case in
rth Bloomfield gravel-mine,
in Nevada County, Califor-
it is probably the largest
mine in work. The tunnel
4 feet in length, 7 feet
feet in cross-section, and
orted cost was £100,000
00). Part of the tunnel is
nd riffled, and it is fur-
with under-currents at its
o the cañon.

bris.—Up to 1889, hydraulic
in California was carried on
interference, but the far-
cupying the lowlands along
a and other rivers complain-
t their lands were being
the channels of the rivers
ing interfered with, efforts

he apparent cause of these

d suits were brought against
ecisions thereto, followed by
of the mines. Considerable
ity, and loss to the miners

893, constituting a Com-
rant permission to mines to
iers constructed works to



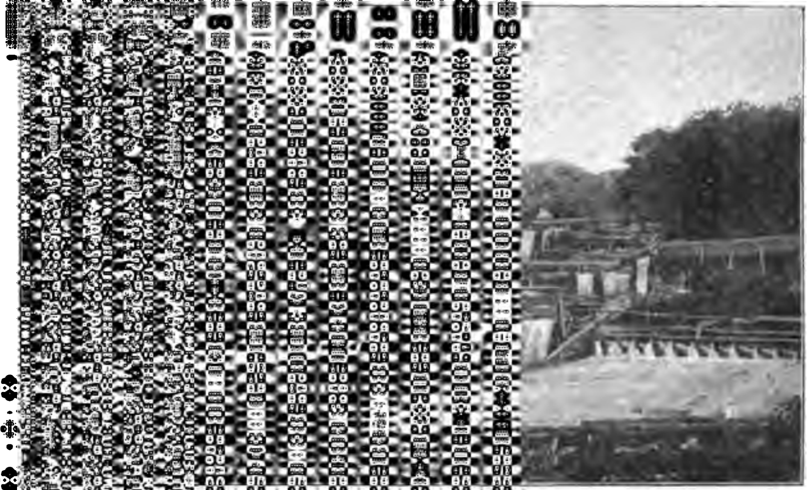
VE, WITH A GRIZZLEY AND AN
CKGROUND.

owing into the streams and
ncisco.

of logs or brushwood placed
into which the tailings or
ater to run off comparatively
(Figs. 30 and 31). All the
ded with convenient cañons
re have to provide settling-
-out ground; and the levels
to certain heights to clear

[illegible] may be either simple [illegible] er-jet ejector, or endless-[illegible] r-power.

[illegible] is manufactured of the [illegible] nd 33), although one has [illegible] e North Bloomfield mine, [illegible] of the closed rising pipe) [illegible] ears to give better results [illegible] ydraulic elevator is com-[illegible] id works so far effectively, [illegible] carried up.



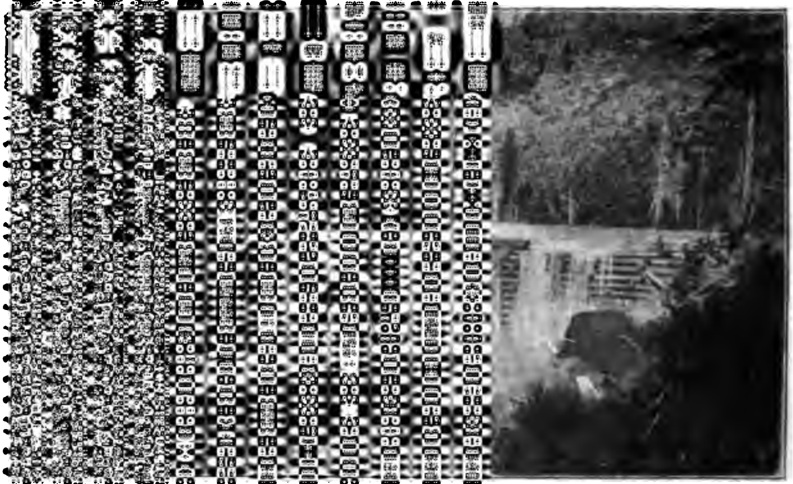
[illegible] EEN THE TWO LOWEST UNDER-[illegible] SE BOULDERS ARE WASHED; [illegible] H THE GRIZZLEY, IS CARRIED

[illegible] ator on the principle of an [illegible] necessary work, with a [illegible]

[illegible] too large to be carried off [illegible] small pieces by blasting [illegible] emoved to the worked-out [illegible] ther conveying apparatus. [illegible] ater-power so far as the [illegible] elton or other power-wheel

a vertical shaft-and-pinion
nd out by a lever (Fig. 35).
s attached to the end of the

Weaverville, Trinity County,
y Mr. Wm. H. Radford by
en by an horizontal water-
l-wheel, and gearing to lift
ations of lifting and turning
labour in so doing.



E TAILINGS FROM AN

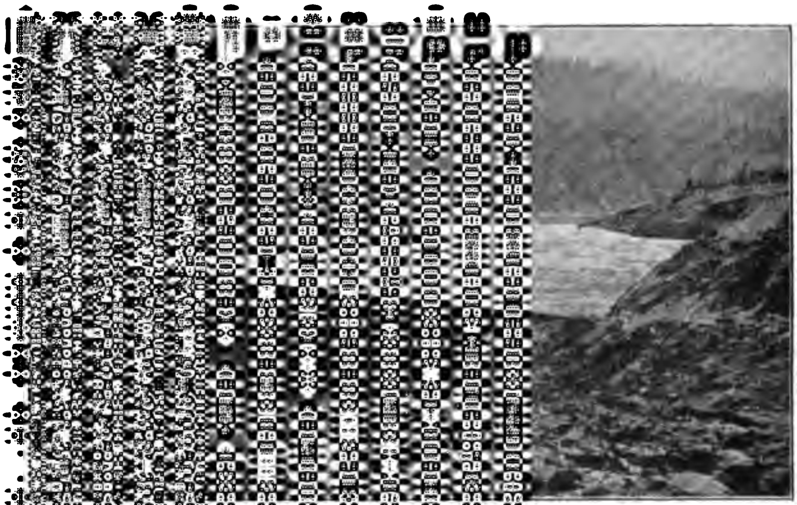
ction City, Trinity County,
ected, which promises to be
range mine, and there seems
rfected, that this mode of
ed when the conditions of

as been made, varying with
ng circumstances, piping is

encing at the head of the
allowed to pass down, and

together, the amalgam
retorted, and the refined

ooms and the blocks are
y particles of gold that
r and carefully examined,
ten found in the crevices
erally, the greatest per-
e first few boxes of the
cleaned up as often as

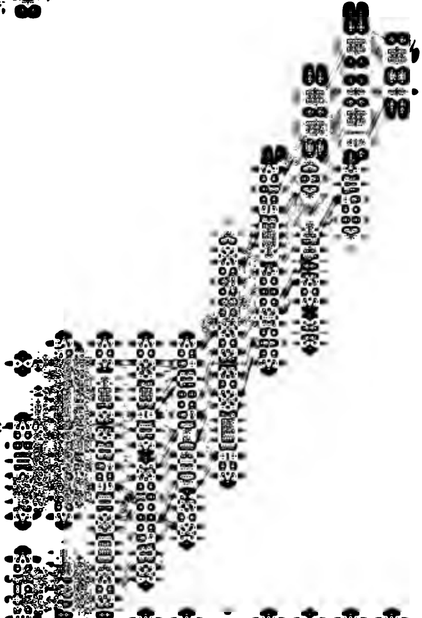


GS. THE DAM (PLACED IN
RAISED AS THE TAILINGS

ay be called the cycle of

procuring it is naturally
position thereof, heights
f boulders, etc., all con-
reliable data exist upon
ld of gold and cost of
orrect surveys have not
ject to give information.

[illegible] for what they are worth :— [illegible] the North Bloomfield mine, [illegible]s, yielded about 2·90 cents [illegible],591,730 cubic yards of top [illegible]ic yard; and 703,200 cubic [illegible]s (16·45d.) per cubic yard. [illegible] a height of 65 feet, and all [illegible]III. shows an estimate made



[illegible]

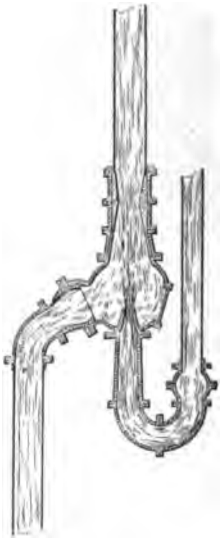


FIG. 33.—SECTION OF AN HYDRAULIC WATER-LIFTER.

[illegible] NG COSTS, ETC.

[illegible]	[illegible]rench Corral.	Manganita.	North Bloomfield.
[illegible]	[illegible] to 100	50 to 150	100 to 280
[illegible]	[illegible]7,532	1,892,826	7,429,893
[illegible]	[illegible]00,000	5,780,000	30,000,000
[illegible]	[illegible]5,000	1,489,000	2,611,686
[illegible]	[illegible]9,000	£297,800	£522,337
[illegible]	[illegible]1·50	26·00	8·70
[illegible]	[illegible]0·75	13·00	4·35
[illegible]	[illegible]1·00	14·60	4·80
[illegible]	[illegible]0·50	7·30	2·40

At the La Grange Company's mine, Stanislaus County, 1,533,728 miner's inches of water washed 2,275,967 cubic yards of gravel, yielding £46,378 ($231,893), or 5d. (10 cents) per cubic yard, at a cost of 3d. (6 cents) per cubic yard.

Mr. A. J. Bowie in his work on *Hydraulic Mining* gives Table IV as a rough guide.

TABLE IV.—CLASSIFICATION OF MINES AND MINING EXPENSES.

		Per Cent.
Class 1.—Grades 1¾ to 2¼ per cent.; banks 20 to 80 feet high, many cobbles, few boulders, cuts light, material easily washed; worth 4d. to 8d. (8 to 16 cents) per cubic yard.	Operating expenses, 35 to 60 per cent. of gross yield, divided as follows:—	
	Labour *	60
	Materials	16
	Water	13
	Explosives	1
	General	10
		100
Class 2.—Grades 4 to 4¼ per cent.; banks 50 to 150 feet high, few boulders, cuts not hard, considerable bank-blasting, material worth 10d. to 1s. 1½d. (20 to 27 cents) per cubic yard.	Operating expenses, 45 to 52½ per cent. of gross yield, divided as follows:—	Per Cent.
	Labour	42
	Materials	13
	Water	17
	Explosives	19
	General	9
		100
Class 3.—Grades 4¼ to 4⅜ per cent.; banks 20 to 100 feet high, many boulders, cuts hard, cement gravel, blasting, material worth 1s. 3d. to 1s. 10½d. (30 to 45 cents) per cubic yard.	Operating expenses, 55 to 65 per cent. of gross yield, divided as follows:—	Per Cent.
	Labour	54
	Materials	13
	Water	15
	Explosives	10
	General	8
		100
Class 4.—Grades 4½ to 5 per cent.; banks 100 to 350 feet high, many boulders, hard cuts, material worth 2½d. to 6d. (5 to 12 cents) per cubic yard.	Operating expenses, 30 to 40 per cent. of gross yield, divided as follows:—	Per Cent.
	Labour	54
	Materials	11
	Water	15
	Explosives	8
	General	12
		100

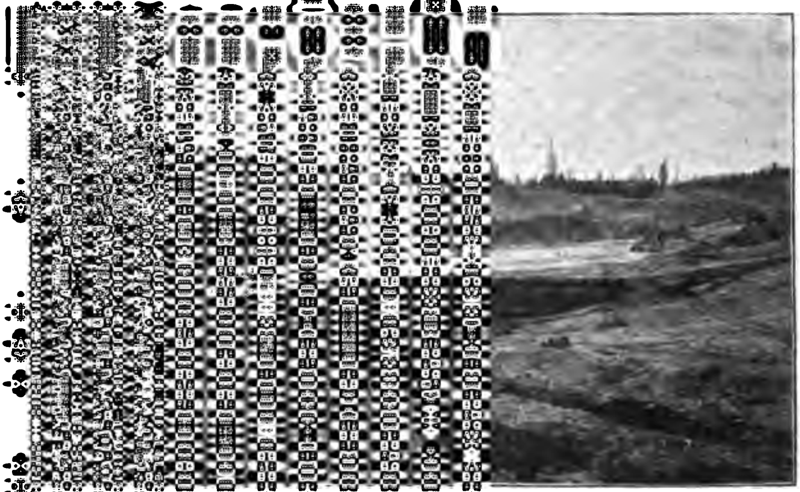
NOTE.—This estimate assumes that each company owns its own water.

* Wages 10s. ($2·50) per day.

Duty of Miner's Inch.—The duty of a miner's inch, or the number of cubic yards of gravel moved by an inch of water, is also a matter varying with the circumstances of the case, and the estimates thereof are necessarily as vague and unreliable as those of the yield of gold.

that the duty per inch of
h. Lieut. Payson, Corps of
as averaging 2·2 cubic yards
½ cubic yards per inch, the
h Flat, 4 mines range from
ne measured by the author
the yield of gold 4d. (8 cents)

of water running in it are
tion of removal of material,
ng power of the water.



HE NORTH BLOOMFIELD MINE.

pping or non-paying material
e valuable contents of a deep-
the lower or bed-rock strata
grade to admit of profitable
mining is resorted to. This
in Butte, Nevada, Placer,
nd is well illustrated by the
Bloomfield, Nevada county,
r channel, whose course was
terly direction. The gravel
f 415 feet, with a volcanic

d-rock, varies in depth
nel varies greatly, some-
150 feet. The bed-rock

feet deep, with a tunnel
annel. A drain-tunnel
charges at about 1 mile

e main pay-channel, and
d. The mined gravel is

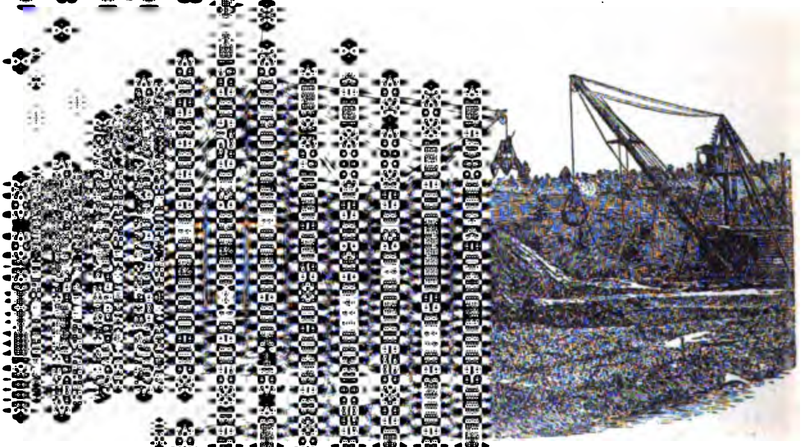
WATER-POWER DERRICK FOR
VING HEAVY BOULDERS.

ce of the water in the

lem of restraining and
ms and pumps so as to
r to be mined.
ing dams to divert the
e a surface of the bed to
he stream and the water
urpose, thus exposing the

the Golden Gate Channel

[illegible] County, are the two most
[illegible] well-built cut and rock-dams,
[illegible] r is brought from a distance
[illegible] h the gravel.
[illegible] ations of this character are
[illegible] certain knowledge can exist
[illegible] the bed of the stream, and
[illegible] onfidence of the miner "that
[illegible] ures are the rule.
[illegible] ine the river-beds by means
[illegible] r combinations of the two,
[illegible] but very little success has
[illegible]



[illegible] OPERATION.

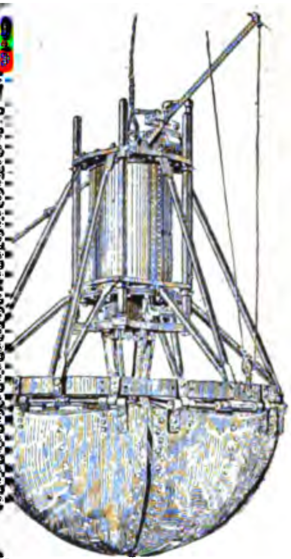
[illegible] dry-mining" is carried on
[illegible] e in Amador County. Here
[illegible] f loam, etc., which has to be
[illegible] about 4 feet in thickness, is
[illegible] derrick with a clam-shell
[illegible] igs. 36, 37 and 38). The
[illegible] f the pit, washed in sluices
[illegible] wise provided, and is treated
[illegible]

[illegible] may be considered as the
[illegible] tments, because if ordinary
[illegible] urveys made of the proposed

uality and value of the
ditches, etc., properly
e very closely determined
ined.

very ordinary matter and
l, therefore, all that is
, is honesty, skill and a
ances of the case.

scribes the operations of
s not present much field



38.—SIDE VIEW OF LIFT, WHEN SHUT.

ion to some points which
Diminishing the size of
r other point of delivery;

s, the vertical surface of
c-grade line, is dependent
regular and in train after
ncement—there does not
eter of such pipes should
ery-end. Thus, a pipe is

40 inches in diameter at the penstock and tapers to 22 inches in a length of 500 feet, and thence is continued 22 inches in diameter to the monitor; another tapers from 27 to 22 inches, and another from 34 to 22 inches.

Of course, it is admitted that, assuming the possession of a certain amount of different sizes of pipe, and a desire to utilize the same, so as to obtain the greatest possible effective pressure at the delivery-end, then it would be proper to lay the line of pipes in diminishing order and so lessen the loss of delivery-head by decreased friction. So far as the author can ascertain, that is not the reason; and if there is any reason, it is done to secure acceleration of velocity, for which the author cannot see any justification.

In Tables I. and II. of syphons and pipe-lines, instances are given of pressures arising from the head of water, and tensional strains therefrom, calculated by the usual formula of T = P.R. It will be noticed that in the case of the Texas Creek syphon, 17 inches in diameter, the strain on the metal of the pipe is nearly 17,000 pounds per square inch, without allowance for rivet-holes, and when these are deducted it must be much more. The metal is ordinary British iron.

In the case of the Spring Valley Water Company's pipe, 30 inches in diameter, the strain is 23,476 pounds per square inch, and, deducting rivet-holes, it is 33,000 pounds per square inch; it also is of ordinary iron.

The North Bloomfield pipe, 22 inches in diameter, is also strained from 16,000 to 17,000 pounds per square inch, and after deducting rivets it is 31,000 pounds per square inch; and like strains occur in other pipes in the tables.

The factor of safety must be very low in these cases, but very few cases occur of pipes giving way when at work. The thickness of metal and size of rivets are less than those of boilers or bridge-work, to which class of work experiments on riveting apply; and it would seem that the idea suggested by Mr. C. H. Moberly * that plates and rivets increase in strength per square inch as the thickness and the diameter become smaller, is supported by the above facts as to pipes, as also by tests made by the author at the University of California.

(2) The laying of the Stuarts' Fork pipe was done by contract, and the joints being riveted up in the usual manner, it may be considered as of a normal character. From close observation of the manner of proceeding, it was clearly proved to be a mere question of the number of joints that could be riveted up in a day, and therefore the cost was at

---

* *Minutes of Proceedings of the Institution of Civil Engineers*, 1882, vol. lxix., page 337; and 1883, vol. lxii., page 226.

the mercy of the riveters. Now, if some other form of joint could be substituted for the riveted one, which should be equally tight under the pressures to be encountered, skilled riveters might be dispensed with. The locked longitudinal joint seems to be a practical one, and if proved to be tight would enable a saving in weight of some 30 per cent. to be made in stock and carriage. An angle-iron flange joint riveted to the pipe, with a gasket and drawing-up bolts, ought to be sufficient, and as the strain is a direct one, no great weight of metal would be required. The pipes could then be laid by ordinary intelligent labourers, and at a rate of probably ten times the speed required for riveted joints.

The PRESIDENT (Mr. J. A. Longden) moved a vote of thanks to Mr. Radford for his interesting paper, and the motion was cordially approved.

Mr. M. WALTON BROWN read the following paper on "Mechanical Ventilators":—

MECHANICAL VENTILATORS.*

REPORT OF THE COMMITTEE OF THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS, AND THE MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.†

BY M. WALTON BROWN.

I.—INTRODUCTION.

At a meeting of the Committee held in London, on June 6th, 1888, Mr. John Daglish was elected chairman, and Mr. M. Walton Brown as reporter and secretary. The Committee agreed that the experiments should be restricted, at first, to those collieries where two fans of different types were erected upon the same shaft, and where experiments could be made upon both fans, when working under precisely the same conditions.

At the same meeting, the instructions to the engineers compiled by the writer were approved (Appendix A), under which the experiments were to be conducted.

The Committee communicated with H.M. Inspectors of Mines and others so as to ascertain the collieries where two fans of different constructions were erected at the same mine, in order that arrangements might be made for experiments upon a number of typical fans, when working under exactly the same conditions.

This information was readily furnished to the Committee, and introductions were obtained to the owners and managers of these collieries.

II.—OBJECT, DESCRIPTION AND PROGRAMME OF THE EXPERIMENTS.

The Committee considered it desirable that all the experiments should be carried out under exactly similar conditions, by the same engineers, with every care and system, in order that the results should afford exact and useful information as to the relative efficiencies and deficiencies of the various ventilators tested.

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* The labours of the Committee were considerably lightened by their being able to use the valuable Report on Mechanical Ventilators made by a Committee of the Société de l'Industrie Minérale, *Bulletin*, 1878, series 2, vol. vii., pages 477 and 713.

† The members of the Committee were:—Sir Lindsay Wood, Bart., and Messrs. W. Armstrong, E. Bainbridge, M. Walton Brown (Reporter and Secretary), T. Forster Brown, T. Carrington,* W. Henry Chambers, J. Daglish (Chairman), T. W. Embleton,* G. B. Forster, W. E. Garforth, W. Garnett, W. H. Greenwood, A. S. Herschel, W. M. Hicks, George May, J. H. Merivale, Joseph Mitchell,* J. Nevin, M. Nicholson, C. E. Rhodes, A. L. Steavenson, H. Stroud and G. Blake Walker. Messrs. W. J. Bird* and T. W. H Mitchell were the Engineers to the Committee and most ably conducted the various experiments. [* Deceased.]

(*a*) *Selection of Ventilators.*

The experiments were solely confined to the merits of the ventilators, irrespective of the ventilation produced in the mine being sufficient for its requirements.

The Committee had a somewhat large list of ventilators in use from which to make a selection, and Table A contains particulars of the fans which were chosen as most suitable for the experiments.

TABLE A.—DIMENSIONS OF VENTILATORS TESTED.

Name of Colliery and Type of Ventilator.	Date of Erection.	Diameter of Fan.		Diameter of Inlet.		Width of Fan.				Revolutions per Minute at Normal Velocity.	No. of Vanes.
						At Periphery.		At Inlet.			
Cwmaman—		Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.		
Guibal	1873	30	0	10	2	10	0	10	0	63·66	10
Waddle... ...	1887	30	0	12	0	1	4	3	6	63·66	20
Great Western—											
Guibal	1876	40	0	14	0	12	0	12	0	47·74	10
Schiele	1885	15	3	8	8	3	9	6	0	125·23	12
National—											
Schiele	1886	15	3	8	10	3	0	6	0	125·23	12
Waddle... ..	1883	45	0	15	0	1	8	4	2	42·44	24
Pelton—											
Guibal	1875	36	0	13	0	12	0	12	0	53·05	10
Waddle... ...	1868	31	7·2	14	1	1	2	3	3	60·44	16
Towneley—											
Schiele	1889	12	0	7	6	2	3	3	6	159·15	12
Waddle... ...	1873	40	0	12	0	1	6	4	8	47·74	24
Wingate Grange—											
Guibal	1871	36	0	13	0	12	0	12	0	53·05	10
Schiele	1886	12	0	7	3	2	0	3	4	159·15	12

The selected ventilators are all centrifugal fans, and may be divided into two classes—(*a*) Ventilators of small diameter running at a high angular velocity; and (*b*) Ventilators of large diameter running at a much lower angular velocity. The first class will comprise the Schiele fans, 12 feet and 15 feet 3 inches in diameter; and the second class, the Guibal fans, 30, 36 and 40 feet in diameter, and the Waddle type of fans, 30, 31·6, 40 and 45 feet in diameter.

(*b*) *Programme of the Experiments.*

The programme of the experiments was drafted so as to afford comparative results for the several ventilators, irrespective of the relative resistances of the mines ventilated by them.

The volume of air produced by a ventilator in the unit of time, through the mine upon which it is erected, is the chief element to be considered in the selection of a ventilator.

The volume exhausted is, however, a variable quantity, dependent upon the velocity of the fan and the resistance of the mine.

These elementary ideas are often overlooked in experimental tests made upon ventilators, and it is sometimes difficult to make use of the results in a satisfactory manner.

The results produced by different fans can, however, be compared with accuracy if they are tested at similar circumferential velocities, and the comparison should be extended by a series of experiments made under the various conditions which may be presented by the workings of the mine, by varying the resistances of the mine to the passage of the air.

(c) *Velocity of the Ventilator.*

The variations of the velocity of the ventilator are eliminated in the comparison of experiments by the application of the principle that for a mine of any degree of resistance the volume of air exhausted by a ventilator is proportional to its velocity. The volume produced by a ventilator overcoming any resistance to the circulation of the air at the speed at which the experiment is made, is transformed by a simple calculation into the volume that might have been produced if the ventilator had been running at any other required velocity.

The point was considered, as to the velocity at which the results given by the various ventilators should be compared. There are known practical limits within which ventilators yield satisfactory results, and it was not difficult to conceive that there was a mean or normal velocity at which all fans might be run for purposes of comparison.

In the case of centrifugal fans, the normal velocity may be determined with some precision. It happens, from their mode of action, that their angular velocity varies inversely with their diameters, and there is no difficulty in producing comparative equality in the lineal velocity of the tip of the vanes of the two classes of fans.

After careful consideration of numerous observations upon the fans proposed to be tested and of other centrifugal fans, it was decided that the normal velocity of the fans to be tested should be taken at 6,000 feet per minute, measured at the tips of the vanes.

The comparison of the volumes and water-gauges produced by the several fans, under various degrees of resistance of the mine, was therefore made under these conditions.

(d) *Resistance of the Mine.*

As regards the variable resistances of the different mines to the circulation of the air, it appeared to the Committee that the idea of the equivalent orifice of the mine was capable of yielding useful and practical results when applied to experiments of the number and nature undertaken by them.

Mr. Daniel Murgue was led to consider that the resistance of any mine could be compared to an orifice in a thin plate, or, in other words, that any mine which was ventilated by a known volume of air under a certain depression or water-gauge was the exact equivalent to an orifice made in a thin plate, which allowed the passage of the same volume of air under the same depression.*

This imaginary orifice forms, so far as the resistances are concerned, the exact mechanical equivalent of the mine under consideration and the area of the orifice may be taken as a measure of the resistance of that mine in comparison with the resistance of any other mine. Consequently, by the idea of the equivalent orifice of the mine, the resistances of all mines can be represented by orifices, from complete closure to the large orifices of 200 square feet found in railway-tunnels.

If the volumes produced by each ventilator through any mine, or through any equivalent orifice (as every mine may be represented by its equivalent orifice) are known, then a curve may be drawn for any fan running at the normal velocity, whose abscissæ are the equivalent orifices or inverse measures of the comparative resistances of the mines, and whose ordinates represent the volumes of air produced.

Such a curve is the characteristic curve of the ventilator, and a comparison of a series of these curves for different types and sizes of ventilators will determine the most suitable ventilator for any mine whose resistance as measured by its equivalent orifice is known.

(*e*) *Experiments.*

A characteristic curve can be constructed, if for any determined useful length, a number of points have been determined by experiments.

A curve can be determined with some accuracy for a limited length by means of at least five points, one corresponding to a mine under ordinary working conditions; two degrees of mines of greater resistances, produced by appropriate obstructions placed in the mine; and two degrees of mines of less resistances than under ordinary working conditions, produced by the opening of separation-doors and drift-doors, by which the entrance of the air to the fan is greatly facilitated.

By these artifices, observations were made upon each fan running at the normal velocity, upon the mine, and upon four other conditions of the mine offering different resistances to the ventilation; or, in other words, the volume of air produced by each fan was determined for at least five different conditions of the mine whose resistances varied to a very considerable extent.

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* *Bulletin de la Société de l'Industrie Minérale*, series 2, 1873, vol. ii., page 445; 1875, vol. iv., page 747; and 1877, vol. vi., page 210.

Two observations were also made with the fans running upon the mine under ordinary working conditions at velocities other than the normal, where possible, one at a higher and the second at a lower speed. In other cases, two speeds were selected lower than the normal velocity, where the boiler-power or heating of the fan-shaft bearings, etc., prevented the ventilator being run at the higher speed.

In most cases, tests were made to ascertain the power absorbed in the engine and fan when running at a low speed, and of the amount of ventilation produced by natural means, with the mine under ordinary working conditions, and the fans at rest.

In a few instances, with the mine under ordinary working conditions, observations were made as to the volumes of air exhausted by each fan at the same depression.

These numerous experiments furnish all the information necessary for a careful study of the various ventilators, not only as to the limits of the practical velocity, but also in respect to their dimensions.

In every instance the experiments were made at a time when the working of the mine was entirely suspended.

(*f*) *Mechanical Efficiency.*

The useful effect of a ventilator expressed in horsepower is the product of the volume of air in cubic feet per minute, the depression in inches of water, and the weight of 144 cubic inches of water in pounds, divided by 33,000 foot-pounds.

The horsepower of the engine was determined from diagrams taken with a Richards indicator in the ordinary manner. This method is, of course, subject to criticism, as being incorrect, as the indicated horsepower is diminished by the inherent resistances of the steam-engine before being applied to the ventilator. Various means were considered for measuring the power applied in turning a ventilator, but they were all in turn reluctantly discarded, as none of them could be applied to all of the ventilators, the subjects of the experiments.

The fan and the engine have been considered as a single machine, and the mechanical efficiency of the system is the ratio of the useful effect to the indicated horsepower, and is therefore somewhat dependent upon the degree of perfection of the engine.

It is evident in ventilators of the same type that the mechanical efficiency falls as the volume decreases. In a theoretically perfect centrifugal fan, the velocity of the circumference produces the theoretical depression, $H_e = \frac{u^2}{g}$*, and the maximum theoretical volume, $V_s = 0{\cdot}65au\sqrt{2}$.† If there were no resistances, or losses of kinetic energy owing to the various imperfections inherent to all classes of ventilators, the mechanical efficiency of the perfect centrifugal fan would be unity. In the case of an ordinary fan in practice running at the same circumferential velocity, various causes co-operate in reducing the depression and the volume of air, and the more the actual volume of air falls below the theoretical volume of air, the efficiency of the ventilator will be similarly varied, and the mechanical efficiency will decrease with the variation of the volume.

(*g*) *Costs.*

The costs, as kindly supplied by the various colliery companies are given, and allow a comparison of economic values, but this can only be of limited extent, as the cost chiefly depends upon factors independent of the ventilator, such as foundations, boilers, fuel, cost of materials, and labour, which varied largely at the time the various ventilators were erected.

(*h*) *Conclusion.*

It will be seen that a considerable amount of work has been entailed in each experiment upon a single fan, at least nine observers being required, without counting several workmen employed to open or close separation-doors, etc.

In many instances serious expenditure was incurred by the colliery companies in alterations required for the exact carrying out of the programme of experiments.

Without ample voluntary assistance the engineers would have failed to carry out the experiments: aid was freely and voluntarily accorded by all the colliery companies, who rendered every possible assistance through their own members and agents, and by the services of such workmen as were required.

The Committee feel their indebtedness, and would here convey their most hearty thanks to the colliery companies and others, who so willingly afforded them every assistance in the experiments.

The thanks of the members are also accorded to the engineers, Messrs. W. J. Bird and T. W. H. Mitchell, for the very able manner in which they conducted the experiments.

* Page 511. † Page 505.

The thanks of the Committee are also accorded to Messrs. A. A. Atkinson, A. Nagel, R. A. S. Redmayne and F. C. Swallow, who are responsible for the correctness of the numerous calculations and illustrations contained in this report.

III.—Experiments.

(*a*) *Description of the Ventilators.*

The six collieries chosen for the experiments were all ventilated by exhausting fans; no colliery, brought under the notice of the Committee, was provided with duplicate compressing ventilating machinery.

All the ventilators tested were well-known types of centrifugal fans, and do not require to be particularly described, beyond the short summarized details of the arrangements of the duplicate fans at each colliery.

(1) *Cwmaman Colliery.*—This colliery is alternately ventilated by a Guibal and a Waddle fan.

The Guibal fan was built by the Grange Iron Company, Limited, of Durham, and erected in 1873. It commenced to work on August 10th, 1874. The only accident had been a broken shaft in July, 1876, causing a stoppage of about three weeks. The fan is 30 feet in diameter and 10 feet wide, the inlet being 10 feet 2 inches in diameter. It has ten blades. The shutter is fixed immovably, the opening being 10 feet 1 inch by 3 feet 6 inches, or an area of 35·29 square feet. At the top, the chimney was 9 feet 9 inches by 7 feet 1½ inches, the area being 69·46 square feet. The engine was originally in duplicate, but now there is one cylinder, 24 inches in diameter and 2 feet stroke. The exhaust steam, when required, can be condensed by means of a Morton ejector-condenser, producing a vacuum of from 10 to 12 lbs. per square inch. A large fan-drift (arched with stone) but somewhat irregular in section connects the fan-chamber with the upcast-shaft, a few feet below the surface (Fig. 1, Plate XV.). At the point where the air was measured, the section was divided into 16 approximately equal areas with a total surface of 112·26 square feet (Fig. 2, Plate XV.).

The Waddle fan was built by Mr. J. R. Waddle, of Llanelly, and erected and commenced working in 1887. It is 30 feet in diameter, 16 inches wide at the periphery and 42 inches at the inlet. The inlet being 12 feet in diameter. It has twenty alternating long and short curved blades. An inverted vertical marine engine, bought second-hand, in 1873, for another purpose, drives this fan by means of helical-teehed gearing. The two cylinders are 40 inches in diameter and 30 inches stroke, and the piston rods 4 3/16 and 4 1/8 inches in diameter respectively. The engine is geared to the fan in the proportion of 70 to 29, and is fitted with ordinary air-pump condensers worked by levers from the cross-heads. There is no fan-drift, as the upcast-shaft discharges the air direct into the fan-chamber (Fig. 1, Plate XV.). The air was measured at the top of the upcast-shaft, at a rectangular frame 10 feet 6½ inches by 8 feet 7 inches (with a transverse bar, 6 1/16 inches wide), divided into 16 equal parts by strings, with a total area of 86·15 square feet. There have been no accidents to this fan. The cost of maintenance is about £18 per annum.

There are two shafts, 66 feet apart. The downcast shaft is elliptical in shape, 15 feet by 9 feet 6 inches, sunk to a depth of 792 feet, cutting the following seams:—The Two-feet-nine-inches coal-seam at 654 feet; the Four-feet coal-seam at 675 feet; and the Six-feet coal-seam at 759 feet. The downcast (winding) shaft is fitted with buntons and rail-guides. It also contains a 9 inches steam-pipe and a 4 inches rising main water-pipe, both of which are carried from the surface to the Four-feet coal-seam. The heating-effect of the steam is shown by the recorded temperatures of the air. A third pipe, 4 inches in diameter, is used for conveying a blower of gas to the surface from a depth of 213 feet (Fig. 3, Plate XV.).

The upcast-shaft is circular and 9½ feet in diameter, and is sunk to the Six-feet coal-seam, at a depth of 792 feet. The portion between the Four-feet and Six-feet coal-seams is dumb, a scaffold closes the shaft just above the level of the Four-feet coal-seam, and all the return-airways enter at the Two-feet-nine-inches coal-seam level at a depth of 675 feet. There are no obstructions whatever in this shaft (Fig. 4, Plate XV.).

The pits are sunk at the rise side of the royalty, most of the coal laying to the dip. The workings are on the longwall system. The position of the water-gauges during the experiments is shown in Fig 1, (Plate XV.), Guibal fan:—No. I, at the inlet of the fan; II, in the fan-drift at the place of air-measurement; III, at the separation-doors at the pit-bottom; IV, at side of fan; and V, in upcast-shaft, 16 feet below the drift to the Guibal fan. Waddle fan:—I, at the inlet of the fan; II, at the top of the upcast-shaft at the place of air-measurement; III, at the separation-doors at pit-bottom; and V, in the upcast-shaft, 16 feet below the drift to the Guibal fan.

The restricted orifices were formed upon the top of the upcast pit.

(2.) *Great Western Colliery.*—The two ventilators in use at this colliery are a Guibal and a Schiele fan (Fig. 5, Plate XV.).

The Guibal fan was built by Messrs. Black, Hawthorn & Co., of Gateshead-upon-Tyne, in the year 1876. It is 40 feet in diameter and 12 feet wide. It is driven by a direct-acting horizontal engine, having a cylinder 36 inches in diameter and 3 feet stroke. The cost, including buildings, was £4,186 5s. 0d. The average annual cost of repairs is £96 8s. 0d., and of stores £192 16s. 9d.

The Schiele fan was constructed by the Union Engineering Company (Messrs. C. Schiele & Co.), of Manchester, in the year 1885. It is 15 feet 3 inches in diameter, and is driven by a horizontal engine, with one cylinder 32 inches in diameter and 3 feet stroke, by belting in the ratio of about 3·2 to 1. The cost, including buildings, was £4,941 15s. 4d. The average annual cost of repairs is £18 12s. 0d., and of stores £140 19s. 1d.

At the Hetty (downcast) shaft, the Four-feet coal-seam, 6 feet thick, is worked at a depth of 1,095 feet, and the Six-feet coal-seam, 6⅝ feet thick, at 1,174½ feet. The No. 2 or upcast-shaft passes through the Four-feet coal-seam at 1,125 feet; the Red coal-seam at 1,229 feet; the Nine-feet coal-seam, 5 feet thick, at 1,264½ feet; and the Five-feet or Lower coal-seam, 4 feet thick, at 1,420½ feet.

The position of the shafts and fans and the relative positions of the water-gauges are shown in Fig. 5 (Plate XV.).

Figs. 6 and 7 (Plate XV.) are plans of the Hetty or downcast-shaft, and the No. 2 or upcast-shaft.

There being no convenient places for the measurement of the air in the fan-drifts, the air was measured at a section 3 feet from the top of each fan's chimney, with an anemometer suitable for use in vertical currents. Figs. 8 and 9 (Plate XV.) represent sections of the places where the air was measured (in the fan chimneys) in the trials of the Guibal and Schiele fans.

The restricted orifices were cut in the respective separation-doors.

(3.) *The National Colliery* is provided with a Schiele and a Waddle type of fan (Fig. 10, Plate XVI.).

The Schiele fan was erected by the Union Engineering Company, of Manchester, in 1886. It is 15 feet 3 inches in diameter, and 3 feet wide at the periphery, the diameter of the inlet being 8 feet 10 inches, and its width 6 feet. It is driven by a horizontal engine with one cylinder, 32 inches in diameter and 3 feet stroke. The engine drives the fan by belting, in the ratio of 3·15 to 1. The cost of engine and fan was £2,100. The average annual cost of stores is £74 7s. 4d.

The Waddle type of fan was erected in 1883 by Messrs. Llewellyn & Cubitt, of Pentre Rhondda. It is 45 feet in diameter, 1 foot 8 inches wide at the periphery, the diameter of the inlet is 15 feet, and the width 4 feet 2 inches. It differs somewhat from the ordinary type of Waddle fan, the curved blades being inclined at a greater angle to a radius. The collar of the fan did not fit very exactly. The fan is driven by an engine with a cylinder 36 inches in diameter and 3 feet 6 inches stroke. The average annual cost of stores is £23 16s. 9d.

The downcast-shaft is 17½ feet in diameter and is fitted with four wire-rope guides, *a*, 1¼ inches in diameter, two being on the outside of each cage. There are two rubbing-blocks, *b*, fixed on each cage, and two ropes, *c*, (2 inches in diameter), are placed between the cages. A water-pipe, *d*, 1½ inches in diameter, takes water from the surface to the Four-feet coal-seam (Fig. 11, Plate XVI.). The position of a byat, at a depth of 300 feet, is shown in Fig. 12 (Plate XVI.). At 1,212 feet, is a landing for the Two-feet-nine-inches coal-seam (Fig. 13, Plate XVI.). The stage for the Four-feet coal-seam is situated at a depth of 1,272 feet, and the pit is sunk to the Six-feet coal-seam at a depth of 1,353 feet from the surface.

The upcast-shaft is 14 feet in diameter, with steam and water-pipes in the shaft (Figs. 14 and 15, Plate XVI.) for a depth of 300 feet from the surface. The landing of the Two-feet-nine-inches coal-seam (Fig. 16, Plate XVI.) is situate at a depth of 1,212 feet from the surface; *a*, *b*, and *c* are guide-ropes, 1¼ inches in diameter, extending from the surface to the Six-feet coal-seam. The Four-feet coal-seam lies at a depth of 1,272 feet, and the shaft is sunk to the Six-feet coal-seam at 1,353 feet.

The position of the fan-drifts (Fig. 10, Plate XVI.) allowed of one common place of measurement for the experiments with both fans, its section being shown in Fig. 17 (Plate XVI.).

The restricted orifices were cut in the separation-doors near each fan.

Speaking-tubes were fitted between the engine-houses and the fan-drift.

The position of the water-gauges is shown on Fig. 10 (Plate XVI.).

(4.) *Pelton Colliery.*—There are three fans at this colliery, two being usually at work. The two fans adjacent to the Busty (upcast) shaft, viz., the Waddle fan and the No. 2 Guibal fan, only were tested (Fig. 18, Plate XVI.).

The Waddle type of fan is 31·6 feet in diameter, and 14 inches wide at the tips of the blades. The diameter of the inlet is 14 feet 1 inch. This fan is driven by a non-condensing horizontal engine, with one cylinder, 24 inches in diameter and 24 inches stroke. This fan was constructed by Messrs. Black, Hawthorn & Co., and erected in 1868. It had 8 long and 8 short vanes, and presented some differences in detail and proportion from the ordinary type of Waddle fan. The cost of fan and buildings was £940. The annual average cost of stores is £41 12s. 0d.

The No. 2 Guibal fan is 36 feet in diameter and 12 feet wide, the diameter of the inlet being 13 feet. It is driven by a non-condensing horizontal engine, with one cylinder, 30 inches in diameter and 30 inches stroke, fitted with variable expansion-gear. A duplicate engine is kept for emergencies. This fan was constructed by the Grange Iron Company and erected in the year 1875. The cost of fan, engines and buildings was £3,600. The mean annual cost of stores is £31 10s. 0d.

The arrangement of the fan-drifts is shown in Fig. 18 (Plate XVI.). The separation-doors, D, were arranged so as to shut off the No. 1 Guibal fan exhausting from the Low Main coal-seam upcast-shaft, the two fans with which the experiments were made exhausting from the Busty upcast-shaft only.

The fan-chambers are closely adjacent to the top of the shaft, only a short length of drift being available for the air-measurements, and it was found necessary to fix the dividing strings in the frames of the separation-doors and in these apertures the air was measured (Figs. 19 and 20, Plate XVI.).

There are five shafts at this colliery of the following diameters and depths:—

Shafts.	Diameter. Feet.	Depth. Feet.	Name of Shaft.
Downcast, No. 1...	7	324	Old Hutton.
„ „ 2..	10	540	Low Main.
„ „ 3...	14	540	Busty.
Upcast, „ 4...	10½	540	No. 1 Fan Return.
„ „ 5...	12½	540	No. 2 „ „

Of these shafts, Nos. 2, 3 and 5 only were affected by the present experiments. The areas and obstructions in these shafts are shown in Figs. 21, 22, 23 and 24 (Plate XVII.). There are no obstructions in the Nos. 1 and 2 upcast-shafts.

Electric bells, fitted by Messrs. John Mills & Son, Newcastle-upon-Tyne, were used for signalling between the engine-houses and the fan-drift.

The positions of the water-gauges during the course of the experiments were as follows:—No. I was placed at the inlet of each fan (Fig. 18, Plate XVI.), and No. II was placed at the top of the Busty upcast-shaft.

The sections of the drift where the air was measured are shown in Figs. 19 and 20 (Plate XVI.), respectively, for the Waddle and Guibal fans.

The restricted orifices were arranged by means of a sliding door placed over the top of the upcast-shaft.

(5.) *The Towneley Colliery* (Lancashire) is provided with a Waddle and a Schiele fan, the relative positions of which are shown in Fig. 25 (Plate XVII.).

The Waddle fan (built by Mr. J. R. Waddle in 1873) is 40 feet in diameter, with an inlet 12 feet in diameter and 4 feet 8 inches wide, the width at the periphery being 1 foot 6 inches. It is driven by a horizontal engine, with a cylinder 32 inches in diameter, and 4 feet stroke. The fan was in bad repair, the curved vanes, in many cases, consisting of wooden-laggings put in to replace the wasted wrought-iron plates. The collar, however, fitted somewhat efficiently.

The Schiele fan was in working condition. It is 12 feet in diameter and has an inlet 7½ feet diameter, and is 3 feet 6 inches wide. It is driven by an engine with one cylinder 26 inches in diameter and 4 feet stroke, by a belt 27 inches wide, the pulleys being in the ratio of (20 feet to 4½ feet) $4\frac{4}{9}$ to 1. The Schiele fan-drift is 6 feet above the level of the Waddle fan-drift.

The fan-drift, which is 12 feet in diameter, was reduced to a square of 8 feet by 8 feet (area 64 square feet), where the air was measured in the experiments upon both fans.

The confined position of the Waddle fan is illustrated in Fig. 26 (Plate XVII.).

It was not considered safe, owing to the condition of the Waddle fan, to run it at a greater speed than 40 revolutions per minute, which was taken as the maximum. The normal speed required 47·74 revolutions per minute.

The position of the several water-gauges is shown on Fig. 25 (Plate XVII.).

The restricted orifices were cut in the separation-doors adjacent to each fan.

(6.) *Wingate Grange Colliery* is provided with a Guibal and a Schiele fan.

The Guibal fan (erected in 1871) is 36 feet in diameter by 12 feet wide, and is driven by a direct-acting horizontal engine, with a cylinder 30 inches in diameter and 2½ feet stroke. The fan and buildings cost £2,280 16s. 8d. The annual cost of stores is £29 12s. 11d. and of repairs about £4 3s. 6d.

The Schiele fan (which was erected in 1886) is 12 feet in diameter, the width at the inlet being 3 feet 4 inches and at the periphery 2 feet, the diameter of the inlet being 7 feet 3 inches. The fan is driven by a horizontal engine, by rope-gearing in the ratio of 2·6 to 1. The cylinder is 2 feet 1 inch in diameter and 2 feet stroke. The fan and buildings cost £1,423 12s. 4d. The annual cost of stores is £38 1s. 11d. and of repairs about £4 3s. 6d.

The Guibal fan was at the time of the experiments working regularly, the Schiele fan being kept standing in reserve in case of any accident occurring to the Guibal fan.

The arrangement of the fans, drifts, separation-doors, etc., is shown in Fig. 27 (Plate XVII.).

The sections of the fan-drifts at the places of air-measurement are shown in Figs. 28 and 29 (Plate XVII.).

There are two shafts, the Lady (or downcast) shaft, and the Lord (or upcast) shaft, each 14 feet in diameter, the average obstructions of which are shown in Figs. 30 and 31 (Plate XVII.).

The shafts pass through the workable coal-seams at the following depths:—

Name of Coal-seam.	Thickness.		Lady Shaft.		Lord Shaft.	
	Ft.	In.	Ft.	In.	Ft.	In.
Five-Quarter	3	8	466	0	—	
Main	5	2	549	6	591	0
Low Main	3	3	671	10	714	0
Hutton	2	10	792	0	—	
Harvey	3	0	912	0	—	
Bottom of shaft ...	—		930	0	736	0

The shafts are 264 feet apart, and a 42 feet fault passes between them. The Five-Quarter and Hutton coal-seams are not at present being worked. The Main and Harvey coal-seams are being worked, and the chief output is from the Low Main coal-seam.

The Lord shaft is at present only open to the Low Main coal-seam. The return-air from the Harvey and the Low Main coal-seams passes up a staple to the Main coal-seam, and along a drift discharging into the Lord shaft.

Coal is at present drawn only at the Lady shaft.

Electric bells were used for signalling between the engine-houses and the fan-drift.

The position of the several water-gauges is shown on Fig. 27 (Plate XVII.).

The restricted orifices were arranged by means of a sliding-door placed in a stopping, C (Fig. 27, Plate XVII.).

(*b*) *Description of the Experiments.*

Unless prevented by unforeseen circumstances, from eleven to twelve experiments were made upon each of the ventilators. The programme consisted of making five distinct experiments upon each ventilator, each of which could be used in determining one of the points of the characteristic curve of the fan, that is, the curve of the volume produced by each ventilator when rotating at the normal velocity, for each of the varied resistances of the mine, or for each of the equivalent orifices from complete closure to very large ones.

(1) *The Factive Mines.*—The series of five factive mines of varying equivalent orifices, were more or less easily obtained by conditions artificially created at each mine, as follows:—

(*a*) The return air-drift was closed by a stopping, having an aperture of about 3 square feet, through which air was admitted to the fan, either from the atmosphere or from the mine.

(*b*) The opening in this stopping was enlarged to about 6 square feet.

(*c*) Under ordinary conditions, at three different speeds of rotation of the fan, one being the nearest speed obtainable to the normal velocity.

For the purpose of somewhat exact comparison, it would be desirable that experiments be made upon one of the ventilators running at such a speed as to produce a water-gauge equal to that produced by the other ventilator running at the normal speed of periphery, upon the mine in each case under ordinary working conditions.

(*d*) The separation-doors were opened, so as to facilitate the entry of air to the fan.

(*e*) The air was admitted freely to the fan, all obstruction to its free access being, if possible, removed.

In several instances an experiment was made to determine the amount of ventilation produced by natural means upon the mine under ordinary working conditions, when the ventilator was standing.

(2) *Natural Ventilation.*—The action of natural ventilation is uncertain and variable in its direction and results; it must therefore be considered to be an occasional aid or occasional resistance to the ventilation produced by mechanical means. The aid, if any, afforded by natural means is much smaller than is usually anticipated. Thus, if a volume of 50,000 cubic feet of air per minute is produced by natural means alone, and in the same direction as the ventilation produced by the ventilator, and if the ventilator alone produces a volume of 200,000 cubic feet of air per minute, then the volume of air produced by the fan and natural ventilation together is not 250,000 cubic feet of air per minute. The squares of the volumes being proportional to the depressions, the sum of the squares of the volumes will be proportional to the sum of the depressions. The calculation of the total volume therefore is not determined by simple addition, but by taking the square root of the addition of the squares of the volumes. The total volume being obtained by the formula:—

$$V_3 = \sqrt{V_1^2 + V_2^2},$$

$$V_3 = \sqrt{200{,}000^2 + 50{,}000^2} = 206{,}155 \text{ cubic feet.}$$

The increased volume due to the positive action in this example of natural ventilation being only 6,155 cubic feet instead of the anticipated 50,000 cubic feet of air per minute.

The result would have been similar, but the volume produced by the fan would have been decreased, if, instead of a positive value of the natural ventilation, a negative value had been used.

A compression or negative (−) water-gauge was observed in some of the experiments made upon the ventilators at the Great Western, National and Towneley collieries. At the Great Western colliery, the readings of the No. II. water-gauge, placed on the top of the upcast-shaft, in experiments (Nos. 2, 3, 4, 5, 6 and 11 on the Guibal fan; and Nos. 1, 2, 3, 4, 5 and 11 on the Schiele fan) with restricted orifices, are of no value, owing to the restricted orifices being placed between the fans and the No. II. water-gauge, or to the opening of doors on the surface.

The readings of the No. II. water-gauge, at the place of air-measurement in experiments at the National colliery (Nos. *a*, 1, 2, 3, 4, 5 and 10 on the Schiele fan; and Nos. *a*, 1, 2, 3, 4 and 5 on the Waddle fan), and at the Towneley colliery (Nos. *b*, *c*, 1, 2, 3 and 4, on the Schiele fan; and Nos. *b*, *c*, 1, 2, 3 and 4 on the Waddle fan), with restricted orifices, are of no value, owing to the restricted orifices being placed between the fans and the No. II. water-gauge.

In several experiments at these three collieries it may be noted that the density and weight per cubic foot of the air in the fan-drift is greater than that of the atmosphere, showing that natural ventilation was acting against the action of the fan.

The Committee, however, with the view of obtaining definite and valuable details, stopped the ventilators and made observations of the volume and the depression produced by natural means alone. The results, as might be anticipated, proved that the current of air was often very small, and almost insufficient to turn the anemometer.

The action of natural ventilation in the experiments need not be considered, as its effects are included in the measurement of the equivalent orifice of the mine. If natural ventilation retards the circulation of the air by mechanical means, the result is merely to decrease the apparent area of the equivalent orifice of the mine, because the resistance of the mine is increased. If natural ventilation accelerates the circulation of the air, the apparent area of the equivalent orifice of the mine will be increased, because the resistance of the mine is diminished owing to its assistance.

What would be the effect upon a ventilator when running in the case where natural ventilation retards that produced by the fan? The obstructive effect may be compared to an increase in the resistance encountered by the air in passing through the mine, and is disposed of in the measurement of the equivalent orifice of the mine, which is slightly diminished in area. Consequently, in order to produce the same volume of air, the ventilator must turn more rapidly when the natural ventilation is opposed to the direction of the mechanical ventilation than when that action is neutral.

If the action of natural ventilation accelerates the mechanical ventilation, the resistances of the mine are reduced, and the measurement of the equivalent orifice of the mine is somewhat larger; the ventilator might then be run at a reduced speed to produce the same volume of air.

In determining the characteristic curve of a ventilator at least five points are requisite, spaced somewhat widely apart, the exact position of any of the points of the curve being immaterial, provided that they record the result of actual and accurate observations. These ideas may be shortly demonstrated :—

A mine M, when the natural ventilation is *nil*, is ventilated under a depression h by a volume V, the equivalent orifice of the mine being a, and V and a are the co-ordinates of a point upon the characteristic curve of the ventilator corresponding to the mine M. If the natural ventilation be not *nil*, in the same mine M, the depression h_1 and volume V_1 will be different from h and V, the orifice a_1 is consequently different from that of the mine M, and is in fact the orifice of M_1. The ventilator and natural ventilation together will produce the volume V_1, under the depression h_1, through the mine M_1, with the equivalent orifice a_1. V_1 and a_1 are the co-ordinates of a point upon the characteristic curve of the ventilator corresponding to the mine M_1, instead of the mine M, upon which it actually works.

The value of the natural ventilation need not be determined, unless the actual area of the equivalent orifice of a mine is required. If its effects are ignored the orifice may be too small or too large, but the difference is rarely great in practice.

(c) *Observations during the Experiments.*

In each experiment, observations were made of (1) the revolutions of the fan and of the engine; (2) the volume of air; (3) the depression; (4) the indicated horsepower; and (5) the pressure and temperature of the atmosphere and of the air of the mine in the fan-drift.

(1) *The Revolutions of the Fan and of the Engine.*—The revolutions of the fans and engines were counted by an ordinary lever engine-counter. Electric bells were placed near where the air was measured in the fan-drift and in the engine-house, by which signals were readily exchanged. An observer with a centre-seconds watch in the engine-house, after the preparatory signal had been given by the observers, gave the starting signal, followed by similar signals at half-minute intervals to the end of the experiment.

An independent observer, with a centre-seconds watch, gave the time at intervals of one minute to another observer, who took note of the position of the indices of the counter at the beginning, at intervals of one minute, and at the end of the experiment (eight minutes). The mean of these results only is recorded, it being found that the readings at intervals of one minute are not discordant with the mean results. The first and last readings of the counter were also taken by another observer, to prevent chance of error, and to avoid having to repeat any experiments whose results might be rendered valueless if the speed of the engine or fan were incorrectly recorded.

Each experiment extended over eight minutes, and the records of the speed taken at intervals of one minute proved that the speed was nearly uniform, as the mean revolutions of the observations for eight minutes are practically the same as any of the single-minute readings.

(2) *The Volume of Air.*—A Casella air-meter or Biram anemometer, fitted with a simple appliance for stopping or starting the counting-gear, was employed to measure the speed of the air. The anemometers were tested at intervals during the course of the experiments and adjusted, so that practically the same correction applied in all the experiments.

In measuring the volume of air it is essential that the area of the place of measurement should be exactly determined. The place of measurement was usually in a length of arching, occasionally at the top of the upcast pit or at the top of the expanding chimney of the ventilator. The fan-drift was walled in every case, and was reduced to a rectangular form of known dimensions, by timber, etc., and accessible in all parts to the observer. Figs. 2, 8, 9, 17, 19, 20, 28 and 29 (Plates XV., XVI. and XVII.) show the sections of the various places of measurement.

The place of measurement was, in all cases, divided into sixteen equal areas by means of vertical and horizontal wires. The anemometer was held for half a minute at the centre of gravity of each of the rectangular divisions without intervals.

Two observers were delegated to make the observations, one handling the anemometer and the other observing the centre-seconds watch and recording the results. The reading of the anemometer for eight minutes was then reduced to the reading for one minute, the correction applied, and the result multiplied by the area of the place of measurement gave the volume of air in cubic feet per minute.

(3) *The Depression.*—The amount of exhaustion produced by the fan was observed by means of an ordinary water-gauge fitted with a U-shaped tube. The oscillations of the column of distilled water were reduced by the use of shot in the constricted portion of the tube and by protecting the end of the tube, by means of a long and thick sleeve of flannel, from the effect of the velocity of the air. Flexible indiarubber tubing was employed to connect each of the water-gauges with the positions where the observations were to be made.

One observation was made at the centre of the fan-drift or place where the air was measured, with the end of the tube pointing to the fan, and at the same time as the readings of the anemometer. Simultaneous readings were also taken at the centre of the inlet to the fan, underground, etc. The readings of the water-gauges were taken at intervals of one minute during the eight minutes of each experiment.

In some experiments, a higher depression was measured at the pit bottom than on the surface.

Although the readings are recorded to 0·001 inch, they are merely the calculated means of readings to 0·01 inch.

(4) *The Indicated Horsepower.*—A Richards indicator was used in all the experiments. Both ends of the cylinder were connected (Fig. 49*) by means of a three-way tap at the point of union, above which the indicator was placed. In cases where there were two cylinders, two indicators were employed simultaneously. Three sets of diagrams were taken during each experiment, at the beginning, at the middle, and at the end.

The indicator-springs were tested for accuracy by weights in the ordinary manner, and no spring was used which showed any material error.

Steam-gauges were fixed in close proximity to the cylinders and were read at intervals of 2 or 3 minutes.

Care was taken in all cases to close all cocks attached to the cylinders while indicator-diagrams were being taken.

The area of the diagram, taken at each end of each cylinder, was measured by means of an Amsler planimeter, and this area divided by the length of the diagram gave the mean height. This height, multiplied by the scale of the spring, yielded the pressure upon the piston in pounds per square inch. The horsepower was calculated from the mean of the pressures, calculated from the diagrams by the following formula:—

$$\text{H.P.} = \frac{a \times l \times 2 \times r \times p}{33{,}000}.$$

In which a is the area of the piston in square inches, after allowing for the area of the piston-rod or rods; l, the length of the stroke of the piston in feet; r, the number of revolutions of the engine per minute; and p, the mean pressure of the steam in pounds per square inch.

(5) *Atmospheric Observations.*—Observations of the pressure and temperature of the air were made, as they are factors in some of the formulæ which are used in the deductions from the results of the experiments.

The instruments used were:—A barometer, and wet and dry-bulb thermometers, in the atmosphere at the surface; and wet and dry-bulb thermometers in the fan-drift.

The instruments were observed and did not vary in any case during the course of an experiment.

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The thermometers had been tested at Kew observatory, and the aneroid barometer was adjusted by comparison with a standard mercurial barometer at intervals.

(*d*) *Direction of the Experiments.*

The experiments were all made on days when the collieries were not at work, with all machinery at rest, so that all the desired experiments could be made. Two or three days, prior to the dates fixed for the experiments, were occupied in making the necessary arrangements, and getting the various appliances into working order.

The observers in the fan-drift were never less than two in number, one handling the anemometer and the second observing the centre-seconds watch and booking the results, together with a few workmen holding lamps, etc. An electric-bell was placed close at hand, so that all the observations might be made simultaneously, convenient signals being previously arranged for the purpose, to be exchanged prior to, and during the experiments, and for their stoppage in case of accident. A stroke of the bell was signalled to all observers at half-minute intervals during the eight minutes' duration of each experiment. The watches at each station were relied upon for the time-observation at such point. The time of starting each experiment was fixed beforehand, and after a warning signal had been received and acknowledged, the observations began at the agreed time, with half-minute signals until the close of the experiment.

The observers in the fan-drift, after placing the anemometer on the end of the rod and the thermometer in position, signalled "ready" to the engine-house, and commenced their observations at the appointed time, unless stopped by signal. The anemometer was held in each of the 16 rectangles into which the air-drift had been divided in succession, and the difference between the observed readings of the anemometer at the beginning and at the end of the experiment was recorded. Observations of the wet and dry-bulb thermometers were made during the course of each experiment.

The observers in the external atmosphere were divided into groups : (*a*) Recording revolutions of engine and fan ; (*b*) reading water-gauges ; (*c*) indicating engine ; and (*d*) recording atmospheric observations.

Two observers recorded the revolutions of the engine and fan, one observing the counter and the second giving the time of beginning and ending the observations. The observer in charge of this watch also exchanged bell signals with the other observers. Observers were stationed at each water-gauge taking readings at each alternate signal of the bell, but the underground observer relied upon the time of his watch. Two observers assisted in taking the indicator-diagrams, one actually taking the diagrams, whilst the second assisted him, closing the drain-cocks when required, registering each diagram as taken, recording the steam pressure at stop-valves, etc.

One observer had general charge of the experiments, and while checking the speed of the engine and fan by direct counting, took opportunities of recording the readings of the barometers, thermometers, etc. In addition, the engineman and his assistant were available for special purposes.

When the observers in the fan-drift signalled that they were ready, a reply was given to commence observations, and the water-gauge was read at intervals of one minute, the reading of the engine-counter was taken, diagrams were taken from each end of the one or more cylinders of the engine at the beginning, middle, and end of the experiment. The observer in charge recorded the readings of the barometer and thermometers, and the observations ceased as soon as the observers in the drift signalled that their results were completed.

These arrangements were carried out most successfully, owing to the assiduous application of all the observers and workmen.

The notes of the observers and the indicator-diagrams were taken at the close of each experiment to the observer in charge, who recorded all the observations on specially prepared sheets, upon which the results of the calculations were afterwards registered.

IV.—CALCULATIONS.

The records of the experiments, after the application of suitable formulæ, gave results which are contained in subsequent tables. The normal velocity of the fans was, as previously specified, determined at 6,000 feet per minute. The volume of air produced at the normal velocity was calculated by the following formula :—[*]

$$V_6 = V \frac{u_6}{u}. \quad . \quad . \quad . \quad . \quad . \qquad (1)$$

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[*] The following notation is used in the various formulæ :—

a, the equivalent orifice of the mine in square feet.
d and d_1, the weights of a cubic foot of the external and internal air.
d_2, the mean weight $(d + d_1) \div 2$.
d_3, the weight of a cubic foot of water.
g, acceleration of gravity, 32·1912 feet per second per second.
H, initial depression in inches of water.
H_o, theoretical depression in feet of air-column.
H_x, theoretical depression in inches of water.

The water-gauge at the normal velocity was calculated by the formula:—

$$h_6 = h \frac{u_6^2}{u^2}. \quad . \quad . \quad . \quad (2)$$

The equivalent orifice was calculated by the formula.

$$a = \frac{V}{60 \times 0{\cdot}65 \sqrt{2g \frac{h}{12} \frac{d_3}{d_2}}}. \quad . \quad . \quad (3)$$

The weight of the air of the atmosphere and of the fan-drift did not vary greatly, but the mean (d_2) of the two weights was used in the preceding formula, which after reducing to a simple form becomes:—

$$a = \frac{V}{90{\cdot}324 \sqrt{h \frac{d_3}{d_2}}}. \quad . \quad . \quad (4)$$

The weight of the air of the atmosphere and of the fan-drift was calculated by means of Mr. James Glaisher's *Hygrometrical Tables*.

The useful effect in the air is calculated by the following formula:—

$$\frac{V \times h \times \frac{d_3}{12}}{33{,}000}. \quad . \quad . \quad . \quad (5)$$

The motive power developed by the engine is calculated by the formula previously mentioned.

The mechanical efficiency is the ratio between the useful effect in air to the motive power.

The theoretical depression produced by the perfect centrifugal fan is calculated by the formula $u^2 \div g$. . . . . . . (6)

The normal velocity has been uniformly assessed at 6,000 feet per minute or 100 feet per second. The normal theoretical depression is therefore the same for all the ventilators, and equal to ($100^2 \div g =$) 310·65 feet of air-column.

h, the observed or effective depression in inches of water.
h_1, motive column in feet of air.
h_0, the difference between H and h, in inches of water.
K, maximum manometric efficiency.
o, orifice of passage of fan.
P, the barometric height in the atmosphere, from which P_1, the pressure of the air in the fan-drift, is deduced, by subtracting the height of mercury due to the water-gauge.
t and t_1, the temperatures of the external and internal air.
u, the speed of the periphery of the fan in feet per minute.
u_6, the normal velocity of the fan, or 6,000 feet per minute.
V, the observed volume in cubic feet per minute.
V_s, theoretical volume of air in cubic feet per second.
V_6 and h_6, the volume and water-gauge at the normal velocity.
v, velocity of the air in feet per second.

This value is, however, usually expressed in inches of water-column calculated by the formula:—

$$H_x = \frac{u^2}{g} \times \frac{d_2}{d_3} \times 12 \quad . \quad . \quad . \quad . \qquad (7)$$

This value varies in the different experiments, between 4·273 and 4·668 inches.

The manometric efficiency is the ratio between the observed and the theoretical water-gauge at the normal velocity.

The results of the calculations are appended to the foot of each column recording the observations made during each experiment. The register of the experiments consists of twelve similar parts, one of which relates to each of the fans tested by the Committee. Each part commences with a table of the dimensions, etc., of the fan and engine, area of the place of air-measurement, etc.

Then follow numerous tables relating to the experiments, with calculations appended. The tables are each followed by a summary of the experiments, which does not require explanation (Appendix B, Tables 1 to 12).

V.—COMPARATIVE RESULTS OF THE EXPERIMENTS.

The results of the experiments as recorded in Appendix B (Tables 1 to 12) contain all the details necessary for the compilation of the comparative tables, Appendix C (Tables 13 to 24), from which valuable conclusions may be deduced.

(*a*) *Relative Volumes Produced by the Ventilators.*

Figs. 33 to 42 (Plates XVIII. to XXVII.) are diagrams exhibiting the characteristic curves of the ventilators when running at the normal velocity of 6,000 feet per minute. Figs. 33 to 38 (Plates XVIII. to XXIII.) show the characteristic curves of the two ventilators tested at each mine. The characteristic curves of the four Guibal fans are shown on Fig. 39 (Plate XXIV.), of the four Schiele fans on Fig. 40 (Plate XXV.), and of the four Waddle fans on Fig. 41 (Plate XXVI.). The mean characteristic curves of the three types of ventilators are shown upon each of the diagrams, and also for purposes of direct comparison on Fig. 42 (Plate XXVII.).

On these diagrams curves are drawn through the points representing the results of each experiment: the abscissæ representing the equivalent orifices or the comparative resistances of the various mines, and the ordinates being the volumes of air produced. These curves are the characteristic curves of the ventilators, and by this means the relative efficiencies of the several ventilators are clearly represented.

For all fans, the characteristic curves begin at the origin, as when the mine is closed the volume of air is necessarily *nil;* thence the lines rise at greater or less angles and variable curves. These curves can readily be understood, if it be assumed that (1) the ventilator is running at the normal velocity, and that (2) the mine is closed by a regulator, which being gradually opened, the volume of air will gradually increase, and this increase is shown by the curve on the diagrams.

The theoretical centrifugal ventilator, free from friction and producing the theoretical depression, will produce volumes of air proportional to the areas of the equivalent orifice, and this characteristic curve is shown by the line *O B* on each diagram.* The inherent resistances of the fan are of material importance, and increase with the volume of air, hence, instead of the line *O B*, the characteristic curve of each ventilator becomes slightly curved and depressed as shown in the various diagrams.

If the characteristic curves of the three centrifugal fans be examined, the superior efficiency of the Guibal fan is apparent for all areas of the equivalent orifice. In the Schiele and Waddle types of fans, the superiority of either fan is not very evident, but the ventilators at the several mines appear to range themselves in the following order:—Great Western (Schiele), Pelton (Waddle), National (Schiele), Towneley (Waddle), Cwmaman (Waddle), National (Waddle), Wingate Grange (Schiele), and Towneley (Schiele). The volumes produced by the Schiele ventilators is highest for those of largest diameter; the volumes in the case of the Waddle ventilators appear to decrease as the diameters increase, but it should be remembered that the fan at the Towneley colliery was old and in bad repair, and that at the National colliery is not of the ordinary type, and should more properly be termed a quasi-Waddle fan.

Table B shows, in figures, the comparative volumes of air produced by each of the ventilators upon mines with equivalent orifices of 10, 20, 30, 40 and 50 square feet. The mean volumes of air produced by each of the types of ventilators on mines with similar equivalent orifices are shown in Table C.

* $V_s = 0{\cdot}65a \sqrt{2g \frac{h}{12} . \frac{d_3}{d_2}}$, if $\frac{h}{12} . \frac{d_3}{d_2} = \frac{u^2}{g}$, and $u = 100$ feet per second, then
$V_s = 0{\cdot}65a \sqrt{2 \times 100^2} = 65a \sqrt{2} = 91{\cdot}924a$ cubic feet per second.

TABLE B.—COMPARATIVE VOLUMES OF AIR PRODUCED BY THE SEVERAL VENTILATORS, WHEN RUNNING AT THE NORMAL VELOCITY OF 6,000 FEET PER MINUTE, FOR VARIOUS AREAS OF EQUIVALENT ORIFICES.

Name of Colliery and Type of Ventilator.	Diameter of Fan.		Volumes of Air per Minute corresponding to Areas of Equivalent Orifices of:—				
			10 Square Feet.	20 Square Feet.	30 Square Feet.	40 Square Feet.	50 Square Feet.
	Ft.	In.	Cubic Feet.	Cubic Feet.	Cubic Feet	Cubic Feet.	Cubic Feet.
Cwmaman—							
Guibal	30	0	41,750	83,750	122,000	156,250	190,000
Waddle	30	0	36,700	73,250	108,500	142,750	175,750
Great Western—							
Guibal	40	0	43,000	86,000	129,000	170,500	211,250
Schiele	15	3	37,500	75,000	112,000	149,000	185,000
National—							
Schiele	15	3	40,500	77,750	111,750	145,500	177,500
Waddle	45	0	38,250	74,000	107,000	138,500	169,750
Pelton—							
Guibal	36	0	44,500	88,750	130,000	168,250	202,500
Waddle	31	7·2	37,750	75,500	111,750	146,750	181,000
Towneley—							
Schiele	12	0	39,250	74,500	105,250	132,750	158,000
Waddle	40	0	39,250	74,500	109,000	142,500	176,000
Wingate Grange—							
Guibal	36	0	43,250	86,500	129,750	170,000	205,250
Schiele	12	0	38,250	74,000	107,500	138,750	169,000

TABLE C.—MEAN COMPARATIVE VOLUMES OF AIR PRODUCED BY VARIOUS TYPES OF VENTILATORS, WHEN RUNNING AT THE NORMAL VELOCITY OF 6,000 FEET PER MINUTE, FOR VARIOUS AREAS OF EQUIVALENT ORIFICES.

Type of Ventilator.	Volume of Air per Minute corresponding to Equivalent Orifices of:—				
	10 Square Feet.	20 Square Feet.	30 Square Feet.	40 Square Feet.	50 Square Feet.
	Cubic Feet.	Cubic Feet.	Cubic Feet.	Cubic Feet.	Cubic Feet.
Guibal	43,125	86,250	127,500	166,250	202,250
Schiele	38,750	75,250	109,000	141,500	172,250
Waddle	38,000	74,250	109,000	142,500	175,500

The diagrams of the characteristic curves have shown the comparative volumes produced by the ventilators tested by the Committee. But it should also be remembered, that as the experiments were confined to mines where two types of ventilators were employed, the results obtained should not and are not intended to be used as indicating the actual comparative volumes of air produced by the most efficient ventilators of the Guibal, Schiele or Waddle types.

(*b*) *Mechanical Efficiencies of the Ventilators.*

The motive power utilized or the percentage of useful effect of each ventilator was determined. In order that the percentages of useful effect obtained in the experiments may be compared, it is evidently essential that, like the volumes of air, they should be reduced to the normal velocity.

It is difficult, however, to conceive what the efficiency would become when reduced to the normal velocity. It may be assumed when the velocity is diminished that the efficiency will decrease, owing to the greater proportionate value of the passive resistances of the ventilator and the engine, and *vice versa;* but the exact law is not known. Under these circumstances, and as many of the experiments were made at velocities approximating more or less closely to the normal velocity, it may be assumed that the percentages of useful effect obtained in the experiments may be applied to the normal velocity without appreciable error.

Figs. 43, 44 and 45 (Plates XXVIII., XXIX. and XXX.) show the curves of the percentages of useful effect of the Guibal, Schiele and Waddle ventilators. The curves of the percentages of useful effect are drawn upon the same abscissæ as the characteristic curves, that is the scale of the equivalent orifices, and the percentages of useful effect are placed as ordinates. These curves begin at the origin, because, when the mine is closed, the work of the engine is entirely absorbed by the passive and other resistances of the ventilator and engine, and consequently both the power utilized and the percentage of useful effect are *nil.* From the origin, the curves rise at various inclinations, then bend and approach more or less closely to the theoretical maximum useful effect, which is the horizontal line corresponding to a useful effect of 100 per cent. or unity.

It will be noted on an examination of the diagrams that the useful effects of the combined ventilators and engines are widely divergent, to a much greater extent than occurs in the case of the characteristic curves of the ventilators. The mean results of the several ventilators and engines are shown on Fig. 46 (Plate XXXI.), for purposes of direct comparison, and they tend to prove that the highest mechanical efficiency may be realized upon mines with areas of equivalent orifices varying from 35 to 40 square feet, beyond which the useful effect begins to diminish. For small equivalent orifices, the useful effect is low, and becomes *nil* at the origin as already explained; while it decreases for larger orifices, owing to a greater proportion of the power being absorbed in overcoming the friction of the large volumes of air passing through the ventilator.

The mean maximum percentage of useful effect of the Guibal ventilator and engine is 54·8 per cent., whilst for the Schiele and Waddle ventilators it is lower. These results are slightly different from those obtained by a comparison of the volumes, and may be explained by the engines being of less efficient types. If the efficiencies of the engines had been the same, the mean curves shown in Fig. 46 would have been similar to the curves of the volumes shown in Fig. 42.

Table D contains the numerical values of the useful effects of each of the ventilators and engines for mines with orifices of 10, 20, 30, 40 and 50 square feet. The mean values of the useful effects of three types of ventilators and engines are recorded in Table E, for similar orifices.

TABLE D.—COMPARATIVE PERCENTAGES OF USEFUL EFFECT OF THE SEVERAL VENTILATORS, FOR VARIOUS AREAS OF EQUIVALENT ORIFICES.

Name of Colliery and Type of Ventilator.	Diameter of Fan.		Percentages of Useful Effect at Areas of Equivalent Orifices of :—				
			10 Square Feet.	20 Square Feet.	30 Square Feet.	40 Square Feet.	50 Square Feet.
	Ft.	In.					
Cwmaman—							
Guibal	30	0	38·9	—	—	—	—
Waddle	30	0	23·2	46·7	57·6	57·3	53·7
Great Western—							
Guibal	40	0	17·3	35·2	49·5	55·0	54·5
Schiele ...	15	3	28·6	48·8	57·6	59·2	58·0
National—							
Schiele	15	3	28·7	41·0	41·2	40·6	40·2
Waddle	45	0	16·0	24·8	28·5	30·2	31·4
Pelton—							
Guibal	36	0	27·5	44·4	53·5	57·0	55·0
Waddle	31	7·2	28·3	40·0	43·3	43·0	42·8
Towneley—							
Schiele	12	0	38·3	52·9	56·0	54·3	52·2
Waddle	40	0	19·1	31·4	39·3	45·0	48·2
Wingate Grange—							
Guibal	36	0	28·6	50·6	55·2	52·6	50·1
Schiele	12	0	30·5	43·2	44·3	43·7	43·1

TABLE E.—MEAN COMPARATIVE PERCENTAGES OF USEFUL EFFECT, FOR VARIOUS AREAS OF EQUIVALENT ORIFICES.

Type of Ventilator.	Percentages of Useful Effect at Areas of Equivalent Orifices of :—				
	10 Square Feet.	20 Square Feet.	30 Square Feet.	40 Square Feet.	50 Square Feet.
Guibal	24·5	43·4	52·7	54·8	53·2
Schiele	31·5	46·4	49·8	49·5	48·4
Waddle	21·6	35·7	42·2	43·9	44·0

The experiments indicate in an unqualified manner that the choice of an efficient engine very materially affects the useful effect of a ventilator: an efficient ventilator being practically valueless when driven by an inefficient engine.

In Fig. 43, the result of experiment No. 1 on the Great Western colliery, Guibal ventilator is omitted, being made at the very low speed of 6¾ revolutions per minute; the low percentage of useful effect obtained in experiment No. 10, is due to the ventilator being run at 33¾ revolutions per minute, a speed much below the normal velocity of 47·74 revolutions per minute, and its corresponding efficiency of about 55 per cent., when the equivalent orifice varies between 40 and 45 square feet.

With the Guibal ventilator at Pelton colliery, the only experiment diverging from the curve is No. 7 (Fig. 43), and this difference appears to be due to the low speed of the ventilator (32⅝ revolutions) during the experiment, as compared with the normal speed (53·05 revolutions).

Experiments Nos. 7 and 6 were made upon the Schiele ventilator at the Great Western colliery under similar conditions, save that the speed was increased from 139⅞ to 171⅝ revolutions, and Fig. 44 (Plate XXIX.) shows that the efficiency of the engine became much greater at the higher speed (59·55 to 67·16 per cent. respectively). It is probable, therefore, that the efficiency of this ventilator and engine will attain its maximum with a speed of about 170 revolutions per minute, and an orifice of about 35 square feet. The result of experiment *a*, at the low speed of 20⅞ revolutions per minute, is omitted from the diagram.

In the case of the Schiele ventilator at the National colliery, divergences from the curve are shown in experiments Nos. 1, 2, 3 and 7 (Fig. 44, Plate XXIX.). The increased efficiency is due to the speed, in each case (137½ and 164¾ revolutions) rising above the normal speed (125·23 revolutions per minute). The efficiency of this plant would probably attain 44 per cent. on an orifice of 20 square feet, and the fan running at a speed of 165 revolutions per minute. The result of experiment *b*, at the low speed of 18¼ revolutions per minute, is abnormal.

Experiments Nos. 5, 6 and 7 upon the Schiele ventilator at the Towneley collieries show, in a very evident manner, that the efficiency of this plant under the same conditions, increases with the speed thus:—

No. of Experiment.	Revolutions per Minute.	Useful Effect. Per Cent.
7	126¼	40·53
6	160¼	47·70
5	176¼	49·57

It is probable that this plant might yield an efficiency of 59 per cent., when exhausting from an orifice of 20 square feet and running at a speed of 175 revolutions per minute.

The divergence in No. 6 experiment upon the Schiele ventilator at

Wingate Grange colliery is due to the low speed (88⅜ revolutions) as compared with the normal speed (159·15 revolutions per minute). The abnormal results of experiments *d* and *e*, are difficult to explain.

No. 2 experiment upon the Waddle ventilator at the Cwmaman colliery, is below the curve of useful effect owing to the speed (43·15 revolutions) being below the normal speed (63·66 revolutions). The highest efficiency, about 59 per cent., appears to be attained at the normal speed on an orifice of 35 square feet.

The results of the experiments upon the quasi-Waddle ventilator at the National colliery are unsatisfactory. The divergences in Nos. 2, 6 and 7 experiments are probably due to errors of observation, and in the case of No. 10 experiment to the velocity (26⅜ revolutions) being below the normal speed (42·44 revolutions per minute).

The results of the experiments upon the Waddle fan and engine at the Pelton colliery are unsatisfactory, and are probably due to their age, having been erected in 1868. No. 5 experiment falls below the medial curve, probably owing to the speed (41½ revolutions) being below the normal speed (60·44 revolutions per minute). The low result of No. *c* experiment is due to the low speed of about 18 revolutions per minute.

The low plant efficiency of the Waddle ventilator at the Towneley collieries is somewhat marked, and is probably due to its condition. The following experiments show how its efficiency varied with the speed :—

No. of Experiment.	Revolutions per Minute.	Efficiency. per Cent.
7	20¾	12·24
6	34⅝	21·54
5	40¼	25·64

These experiments show that if this plant had been run at the normal speed (47·74 revolutions per minute) the efficiency might have realized upwards of 50 per cent. upon orifices of 30 square feet.

(*c*) *Relations of the Volume and Depression produced by Centrifugal Ventilators.*

The height of motive column h_1 in feet of air produced by a difference of temperature or by mechanical means is the cause of the motion of air in mines, and the principles of mechanics show (if there be no friction) that the velocity produced is equal to that acquired by a body falling from the same height as that of the head of motive column—

$$v = \sqrt{2gh_1} \quad . \quad . \quad . \quad . \quad . \quad (8)$$

Consequently, the theoretical volume of air passing through any equivalent orifice of area a will be—

$$V_s = va = a\sqrt{2gh_1}; \quad . \quad . \quad . \quad . \quad (9)$$

if h represent the height of the depression in inches of water of a density d_3, and d_2 the density of air, then—

$$h_1 = \frac{h}{12} \cdot \frac{d_3}{d_2}. \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

Substituting this value (10) in the preceding equation (9), then—

$$V_s = a\sqrt{2g\frac{h}{12} \cdot \frac{d_3}{d_2}}. \quad . \quad . \quad . \quad . \quad (11)$$

The actual volume of air per second, owing to the action of the *vena contracta*, is—

$$V_s = 0{\cdot}65\, a\sqrt{2g\frac{h}{12} \cdot \frac{d_3}{d_2}}; \quad . \quad . \quad . \quad (12)$$

and the volume of air per minute will be—

$$V = 60 \times 0{\cdot}65\, a\sqrt{2g\frac{h}{12} \cdot \frac{d_3}{d_2}}. \quad . \quad . \quad . \quad (13)$$

The value of the equivalent orifice is then obtained by deduction—

$$a = \frac{V}{90{\cdot}324\sqrt{h\frac{d_3}{d_2}}}. \quad . \quad . \quad . \quad . \quad . \quad (14)$$

The theoretical depression, in feet of air-column, produced by a perfect ventilator is

$$H_0 = \frac{u^2}{g}, \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

or in inches of water—

$$H_x = \frac{u^2}{g} \times \frac{d_2}{d_3} \times 12. \quad . \quad . \quad . \quad . \quad . \quad (16)$$

The depression H_0 or H_x is not realized in practice owing to the various imperfections inherent to all classes of centrifugal ventilators; and the equation becomes, for the value of the initial depression produced when the ventilator is exhausting from a closed chamber adjoining the inlet—

$$H = K\frac{v^2}{g} \times \frac{d_2}{d_3} \times 12, \quad . \quad . \quad . \quad . \quad (17)$$

in which K is a fraction representing the maximum manometric efficiency realized by the centrifugal ventilator.

It may now be assumed that the centrifugal ventilator is placed upon a mine, and runs at a constant speed. Adhering to the theory of the equivalent orifice, it may be assumed that the mine may be replaced by an orifice a in a thin plate whose area can be varied as desired. If the equivalent orifice be entirely closed, the ventilator will produce the initial depression H.

If an opening be made between the mine and the closed chamber, and gradually enlarged, the depression decreases as the volume of air traversing the ventilator increases, and is reduced to *zero*, when the opening or equivalent orifice is infinite in area. If h_0 represents this gradual decrease of the initial depression, then the effective depression may be expressed by the equation—

$$h = H - h_0, \quad . \quad . \quad . \quad . \quad . \quad (18)$$

in which h_0 may increase in value from *zero* to H.

The difference h_0 between the initial and effective depressions is evidently due to the defective construction of the ventilator, and this loss increases in proportion as the volume of air produced absorbs an increasing fraction of the initial depression.

If o be an orifice representing the difficulty of the passage of air through the ventilator, the mine and the ventilator are then represented by two orifices a and o, placed one behind the other, and successively traversed by the air-current induced through the orifice a by the depression h, and through the orifice o by the depression h_0. The various values are represented by the formulæ—

$$V_s = 0·65\, a \sqrt{2g \frac{h}{12} \cdot \frac{d_3}{d_2}}; \text{ and} \quad . \quad . \quad (19)$$

$$V_s = 0·65\, o \sqrt{2g \frac{h_0}{12} \cdot \frac{d_3}{d_2}}. \quad . \quad . \quad . \quad (20)$$

The following proportions results from the preceding formulæ:—

$$\frac{h_0}{h} = \frac{a^2}{o^2}; \text{ and } h_0 = h\frac{a^2}{o^2}. \quad . \quad (21 \text{ and } 22)$$

If the latter value (22) be substituted in the preceding equation (18), it becomes—

$$h = H - h\frac{a^2}{o^2}. \quad . \quad . \quad . \quad . \quad . \quad (23)$$

The actual depression—

$$h = \frac{H}{1 + \frac{a^2}{o^2}} = \frac{Ho^2}{a^2 + o^2}, \quad . \quad . \quad . \quad (24)$$

or substituting the value of H, as already determined (17),

$$h = \frac{Ka^2}{g\left(1 + \frac{a^2}{o^2}\right)} \cdot \frac{d_2}{d_3} \cdot 12 \quad . \quad . \quad . \quad . \quad (25)$$

The preceding formula shows that the manometric efficiency is a variable expression, increasing with the resistance of the mine, and that the maximum is attained when the orifice is at its minimum area or entirely closed; and that the depression produced, if other conditions remain constant, varies with the square of the speed of the ventilator. This formula also makes the concession that the manometric efficiency is somewhat constant for ventilators of all reasonable and similar dimensions of the same type.

The actual volume of air is obtained by the introduction of the value of h, obtained by equation (24) into equation (13),

$$V = 60 \times 0{\cdot}65\, a \sqrt{\frac{2g\ H}{1 + \frac{a^2}{o^2}} \cdot \frac{d_3}{d_2 \,.\, 12}}\,; \quad . \quad . \quad (26)$$

and introducing the value of H, as determined by formula (17), then the volume of air per minute after reduction is—

$$V = 39\, au \sqrt{\frac{2K}{1 + \frac{a^2}{o^2}}}, \text{ or} \quad . \quad . \quad . \quad (27)$$

$$V = 39\, u \sqrt{\frac{2K\, a^2\, o^2}{a^2 + o^2}}. \quad . \quad . \quad . \quad . \quad (28)$$

This formula shows, if the speed of the centrifugal ventilator remains constant, that (1) the volume varies inversely with the resistance of the mine, and becomes *nil* when the resistance of the mine is infinite or when the inlet from the mine is closed; that (2) the volume increases when the orifice of the fan or (and) the orifice of the mine is increased; that (3) the volume varies with the speed of the centrifugal ventilator if other conditions remain constant; and that (4) the volume produced by small ventilators can never equal those produced by large ventilators, as the orifice of the ventilator, which measures the resistance of the fan to the passage of the air, must necessarily be less for a small than for a large ventilator.

It may also be recognized that the various formulæ apply to centrifugal ventilators, whether air is being exhausted from or forced into a mine.

The connexion between the volume, the depression, and the equivalent orifice of the mine cannot be easily explained. It is, however, readily recognized that the volume increases as the depression falls when the orifice of the mine becomes larger. This explanation is more easily recognized if a drawing be made in which the increasing values of the orifice of the mine are placed as abscissæ: this line may represent a long rectangular orifice, closed by a sliding-door which may be opened as desired. The corresponding values of the volumes of air and the depressions produced are drawn thereon as ordinates. The two resultant curves are reproduced in Fig. 32 (Plate XVII.)

The depression commences when the mine is closed with its initial value of $Ku^2 \div g$; and as the orifice of the mine is enlarged the effective depression gradually falls and would become *nil* when the orifice of the mine is infinite in area; that is, when the initial depression is absorbed in overcoming the resistance of the air in passing through the ventilator when exhausting freely from the atmosphere.

The curve of the volume commences at the origin because the yield is *nil* when the orifice of the mine is closed. Thence it rises rapidly, gradually bends, and terminates in a horizontal line, where the asymptote has for its ordinate the volume $39\ ou\ \sqrt{2K}$. This volume is produced by the ventilator when it is not applied to any mine, and the atmosphere has free access to the inlet of the ventilator.

(*d*) *Results of the Experiments.*

(1) *Fundamental Formulæ.*—The results of the experiments may now be examined in order to establish the truth of the two fundamental formulæ of centrifugal ventilators (25 and 28). In order to simplify the verification, the two formulæ, by eliminating from them the equivalent orifice a, may be combined into one, and the following equation is obtained:—

$$h = \frac{Ku^2}{g} \cdot \frac{d_2}{d_3} \cdot 12 - \frac{V^2}{39^2\ 2g\ o^2} \cdot \frac{d_2}{d_3} \cdot 12 \quad . \quad . \quad . \quad (29)$$

If the initial depression $Ku^2\, d_2\, 12 \div g\, d_3$ be replaced by H, and the constant $12 \cdot d_2 \div 39^2\ 2g\ o^2\ d_3$ by M, the preceding formula becomes:—

$$h = H - M\, V^2, \quad . \quad . \quad . \quad . \quad (30)$$

in which

$$M = \frac{0{\cdot}000{,}122{,}546\ d_2}{o^2\, d_3} \quad . \quad . \quad . \quad (31)$$

Equation (30) has the advantage of avoiding the calculation of the equivalent orifice of the mine, and if the ordinates h, and the abscissæ V^2 be drawn, the co-ordinates of the results of the various experiments should form a straight line. This formula should be applied to the results of all experiments upon centrifugal ventilators, as it is the most convenient method of ascertaining the correctness of the results.

The formula is applicable irrespective of any of the numerous theories respecting the ventilation of mines and of the varying effects produced by natural ventilation.

The value of M can only be calculated with difficulty from the results of experiments.

Tables 25, 26, 27 and 28 (Appendix D) record the results of experiments upon the Guibal ventilators at the Cwmaman, Great Western, Pelton and Wingate Grange collieries, reduced to the normal speed of 6,000 feet per minute. The equations of the straight lines passing through or adjacent to the various points are shown in Table F.

TABLE F.—GUIBAL VENTILATORS.

Name of Mine.	$h = H - MV^2$.
Cwmaman	$h = 2{\cdot}606 - 0{\cdot}000{,}000{,}000{,}045{,}000\ V^2$.
Great Western	$h = 2{\cdot}635 - 0{\cdot}000{,}000{,}000{,}003{,}742\ V^2$.
Pelton	$h = 3{\cdot}058 - 0{\cdot}000{,}000{,}000{,}014{,}600\ V^2$.
Wingate Grange	$h = 2{\cdot}996 - 0{\cdot}000{,}000{,}000{,}012{,}400\ V^2$.

The observed depressions do not all approach the calculated straight lines, but they do so with sufficient accuracy to establish the truth of the theory applied to centrifugal ventilators.

Tables 29, 30, 31 and 32 (Appendix D) show the results obtained by the Schiele ventilators at the Great Western, National, Towneley and Wingate Grange collieries. The equations for the mean straight lines are recorded in Table G.

TABLE G.—SCHIELE VENTILATORS.

Name of Mine.	$h = H - MV^2$.
Great Western	$h = 2{\cdot}088 - 0{\cdot}000{,}000{,}000{,}008{,}000\ V^2$.
National	$h = 2{\cdot}421 - 0{\cdot}000{,}000{,}000{,}023{,}200\ V^2$.
Towneley	$h = 2{\cdot}250 - 0{\cdot}000{,}000{,}000{,}031{,}150\ V^2$.
Wingate Grange	$h = 2{\cdot}138 - 0{\cdot}000{,}000{,}000{,}019{,}400\ V^2$.

The irregularities shown in the tables may in some cases be explained by the inconvenient position of the places where the air was measured, but they generally sustain the accuracy of the formulæ.

Tables 33, 34, 35 and 36 (Appendix D) contain the results derived from the experiments upon the Waddle ventilators at the Cwmaman, National, Pelton and Towneley collieries. The straight-line equations are detailed in Table H.

TABLE H.—WADDLE VENTILATORS.

Name of Mine.	$h = H - MV^2$.
Cwmaman	$h = 1{\cdot}913 - 0{\cdot}000{,}000{,}000{,}004{,}179\ V^2$.
National	$h = 2{\cdot}009 - 0{\cdot}000{,}000{,}000{,}008{,}900\ V^2$.
Pelton	$h = 2{\cdot}142 - 0{\cdot}000{,}000{,}000{,}004{,}170\ V^2$.
Towneley	$h = 2{\cdot}185 - 0{\cdot}000{,}000{,}000{,}008{,}080\ V^2$.

With few exceptions, these tables afford an excellent verification that the theory of centrifugal ventilators is in exact accordance with the results of the experiments, with the reservations previously expressed.

It would appear from the twelve before-mentioned tables that in the case of mines with small equivalent orifices the results are lower than the results with larger orifices. This loss of depression may be attributed to many causes: to the mal-adjustment of the sliding-shutter (where such an appliance is attached to a centrifugal ventilator) and to the inclination of the vanes, which are only suitable in the case of any centrifugal ventilator to a given volume of air, etc.

Consequently, the theoretical straight line cannot be followed up to the first ordinate, as it bends when applied to small values of the equivalent orifice more or less rapidly, according to the imperfections of the ventilator.

(2) *Manometric Efficiencies.*—The manometric efficiencies K of the various ventilators may now be calculated from the constants H, determined by the equations and tables as detailed in Table I.

TABLE I.—GUIBAL, SCHIELE AND WADDLE VENTILATORS.

Type of Ventilator and Name of Colliery.	Mean Theoretical Depression, H_x.	Initial Depression, H.	Manometrical Efficiency, K.
	Inches.	Inches.	
Guibal—			
Cwmaman	4·278	2·606	0·609
Great Western ...	4·394	2·635	0·600
Pelton...	4·603	3·058	0·664
Wingate Grange ...	4·475	2·996	0·669
Means	4·437	2·823	0·636
Schiele—			
Great Western ...	4·426	2·088	0·471
National	4·354	2·421	0·556
Towneley	4·490	2·250	0·501
Wingate Grange ...	4·430	2·138	0·482
Means	4·425	2·224	0·502
Waddle—			
Cwmaman	4·320	1·913	0·442
National	4·375	2·009	0·459
Pelton...	4·606	2·142	0·465
Towneley	4·451	2 185	0·491
Means	4·438	2·062	0·464

The results recorded in Table I., show that the Guibal ventilator fitted with expanding-chimney and so-called sliding-shutter affords the best results; the Schiele ventilator with the expanding chimney being next in position; and the Waddle type of open-running fan is third.

(3) *Orifices of the Ventilators.*—The orifices of the ventilators may now be calculated from formulæ (31), deducing therefrom that—

$$o = \sqrt{\frac{0{\cdot}000{,}122{,}546\ d_2}{\mathrm{M}\ d_3}} \quad . \quad . \quad . \quad . \qquad (32)$$

The following table (J) contains the essential dimensions, etc., of the several ventilators, together with the values of the orifices of passage of the ventilators as determined by the preceding formula.

TABLE J.—GUIBAL, SCHIELE AND WADDLE VENTILATORS.

Name of Colliery and Type of Ventilator.	Diameter of Fan.		Width of Fan at Inlet.		Diameter of Inlet of Fan.		Area of Inlet of Fan.	Orifice of Passage of Fan.
	Ft.	In.	Ft.	In.	Ft.	In.	Square Feet	Square Feet.
Guibal—								
Great Western ..	40	0	12	0	14	0	153·94	196
Wingate Grange	36	0	12	0	13	0	132·73	108
Pelton	36	0	12	0	13	0	132·73	101
Cwmaman ...	30	0	10	0	10	2	81·18	55
Schiele—								
Great Western ...	15	3	6	0	8	8	118·00	134
National... ...	15	3	6	0	8	10	122·56	78
Wingate Grange	12	0	3	4	7	3	82·56	86
Towneley ...	12	0	3	6	7	6	88·36	68
Waddle—								
National... ...	45	0	4	2	15	0	176·71	127
Towneley ...	40	0	4	8	12	0	113·09	134
Pelton	31	7·2	3	3	14	1	155·77	190
Cwmaman ...	30	0	3	6	12	0	113·09	184

The orifices of the several ventilators appear to vary with the diameter of the fan, the construction and width of the vanes, and the diameter of and width at the inlet or the area afforded to the passage of the air.

APPENDIX A.

OBSERVATIONS TO BE MADE, AND INSTRUCTIONS TO THE ENGINEERS.

Six separate experiments shall be made upon each ventilator, in which the friction of the mine is varied, as follows;—(*a*) The return to the ventilator closed. (*b*) The return to the ventilator closed, with the exception of an opening of 3 square feet. (*c*) The opening doubled in area. (*d*) The mine under ordinary working conditions, with all machinery at rest (hauling-engines, winding-engines, etc.) (*e*) The entrance of air facilitated by opening some doors. (*f*) Air admitted as freely as possible from the atmosphere.

In each trial, the six experiments shall be made in the above-named order, and as nearly as possible at the normal speed of periphery, subject of course to the ability of the engines to drive the fans at the required speed when passing large volumes of air.

Two more experiments shall also be made with the mine under ordinary conditions, and the fan running at higher and lower speeds.

The normal speed of periphery shall be taken at 6,000 feet per minute.

In each experiment, observations shall be made of—(*a*) The number of revolutions per minute of the fan and engines. (*b*) The volume of air. (*c*) The water-gauge. (*d*) The indicated horse-power. (*e*) The height of the barometer. (*f*) The temperature of the air.

NOTES.

(*a*) The revolutions of the fan and engines shall be counted by an ordinary engine-counter, and, if possible, two independent observers shall undertake this duty.

(*b*) The Volume of Air.—A Casella air-meter or Biram anemometer shall be employed, provided with some simple form of stopping and starting gear, say, started by the tension of a string and stopped by the reaction of a spring; that is to say, the revolutions will be recorded so long as the string is pulled tight.

The air-measurements shall be made at the same point in (1) the return air-way and in proximity to the inlet of the fan, and also at (2) the inlet (or inlets) and in (3) the shaft. If possible a length of arching shall be taken, and the place of measurement must be of some regular geometrical form. If all parts are not accessible to the observer, the place of measurement must be reduced in size by a rectangular wooden frame or doorway.

The area of the place of measurement must be divided into 16 equal areas, and a reading of the anemometer taken in each at its centre of gravity. The division shall be made by means of horizontal and vertical strings, as shown in Figs. 47 and 48.

The anemometer shall be held for 30 seconds in each position, without intervals between the readings. Two observers shall attend to this, one to handle the anemometer (standing at one side) and the other to observe the seconds' watch and book the results.

When the resistance of the mine is varied, the position of the fan shutter or other appliance for modifying the useful effect of the fan, shall be tested, if practicable, to ascertain the position which yields the highest water-gauge at the normal speed.

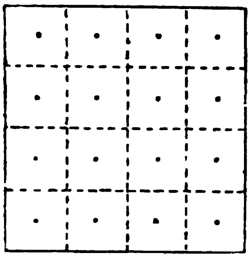

Fig. 47.

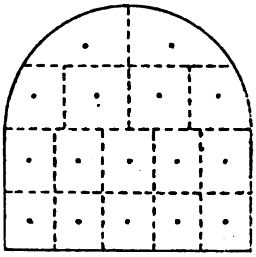

Fig. 48.

The anemometers shall be tested at intervals with the same efficient machine.

(*c*) The water-gauge readings shall be made at the centre of the drift (where the air is measured) with the end of the tube pointing to the fan, and at the same time as the anemometer readings. Simultaneous readings must also be taken at the centre of the inlet to the fan. The end of the tube shall be protected by a flannel cap from the effects of velocity. The readings shall be made every 30 seconds.

The water-gauge used in the experiments shall be of the ordinary form. Distilled water shall be used in the water-gauge. Flexible indiarubber tubing will be required to connect the instruments with the points of observation.

(*d*) The indicated horsepower shall be obtained by means of a Richard indicator. Both ends of the cylinders shall be connected, as shown in Fig. 49, with a three-way cock at the point of union, and above which the indicator shall be placed. If there are two cylinders, two indicators shall be simultaneously employed. By this means both cylinders and both ends of each cylinder will be indicated almost simultaneously. Three sets of diagrams shall be taken during each experiment, at the beginning, middle and end.

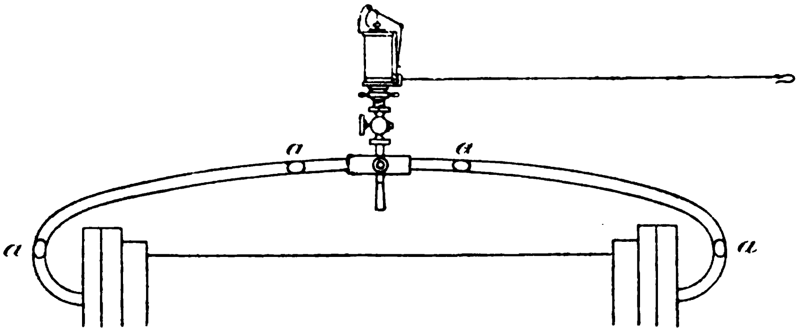

Fig. 49.

Experiments shall also be made to determine the friction of the engine without any air passing through the fan, or by detaching the fan from the engine where possible.

The indicators shall be tested by weights in the ordinary manner.

(*e*) and (*f*) The readings of the barometer and thermometer in the open air, and of the thermometer alone in the drift, shall be registered. The hygrometric conditions of the inner and outer airs shall also be recorded.

Generally, all the experiments shall be made under similar conditions, either when the pits are idle or otherwise. All time observations shall be made with a centre-second watch.

Additional information shall be obtained as under :—(1) Depths and diameters of downcast and upcast shafts. (2) Obstructions (if any) in shafts, with sketches. (3) Distance apart of the shafts, with working sketches of seams. (4) Difference in surface-level of shafts. (5) Temperature at top of upcast and downcast shafts; temperature at middle of upcast and downcast shafts; temperature of bottom of upcast and downcast shafts; if boilers, etc., are in use underground, the temperatures should also be observed (where possible) at the point where the smoke is delivered into upcast, with sketch and dimensions of the smoke-drift and volume of air passing through it. (6) Dimensions of fan, distance from pit, and dimensions of fan-drift (with plans). (7) Dimensions of engines. (8) A record of the steam-pressure at the time of taking the indicator-diagrams. (9) A record of the water-gauge at the bottom of the pit, where possible. (10) The date of erection of the fan and engines. (11) The original or estimated cost (and date) of fan, engine, boilers, building, etc. (12) The cost of maintenance, being the actual cost of stores and repairs of fans and engines. (13) Particulars of all accidents, and duration of stoppages of fan since erection.

Instruments required:—2 water-gauges: 100 feet of indiarubber tubing with wire core; 2 flannel caps for tubing; 2 thermometers, wet and dry bulb; 3 anemometers; 2 Richard indicators; 1 set of reducing-gear; 2 Bourdon steam-gauges, 60 and 150 lbs.; 2 centre-second watches; 1 aneroid barometer; 2 Harding counters; 2 three-way cocks; tool-chest; ratchet-brace and 4 drills; screw-spanner; pipe-tongs; pincers; pipe-cutter; callipers; stock and dies; taps and key; oil-tin; short lengths of steam-pipe of various diameters, etc.

APPENDIX B.—TABLES 1 AND 2.—EXPERIMENTS OF OCTOBER 27TH, 28TH AND 29TH, 1888, UPON THE GUIBAL AND WADDLE FANS AT CWMAMAN COLLIERY.

DIMENSIONS, ETC., OF THE GUIBAL FAN.

Description	centrifugal fan of Guibal type.
Diameter	30 feet.
Width, at inlet	10 „
„ at periphery	10 „
Diameter of inlet	10 feet 2 inches.

Normal velocity (6,000 feet per minute =) 63·66 revolutions per minute.

DIMENSIONS, ETC., OF THE ENGINE.

Number of cylinders	one.
Diameter of the piston	24 inches.
„ of piston-rod, fore end	$3\frac{3}{4}$ „
Mean effective area of the piston	446·90 square „
Stroke of piston	24 „
Ratio of transmission	direct, as one to one.

Exhaust steam condensed by Morton ejector-condenser.

SUNDRY PARTICULARS.

Area of place of measurement (Fig. 2, Plate XV.)	112·26 square feet.

DIMENSIONS, ETC., OF THE WADDLE FAN.

Description	centrifugal fan of Waddle type.
Diameter	30 feet.
Width, at inlet	3 feet 6 inches.
„ at periphery	1 foot 4 „
Diameter of inlet	12 feet 0 „

Normal velocity (6,000 feet per minute =) 63·66 revolutions per minute.

DIMENSIONS, ETC., OF THE ENGINE.

Number of cylinders	two.
Diameter of the pistons	40 inches.
„ of right-hand piston-rod, fore end	$4\frac{3}{16}$ „
„ of left-hand piston-rod, fore end	$4\frac{1}{8}$ „
Mean effective area of the pistons	1,249·90 square „
Stroke of pistons	30 „
Ratio of transmission	by helical gearing, as 70 to 29.

SUNDRY PARTICULARS.

Area of place of measurement	86·15 square feet.

APPENDIX B.—TABLES 1 AND 2.—CWMAMAN COLLIERY.—

Type of Ventilator	Waddle.					
Date 1888	Oct. 28	Oct. 28	Oct. 28	Oct. 29	Oct. 29	Oct. 29
Time	12 50 p.m.	1 8 p.m.	1 30 p.m.	5 3 p.m.	5 30 p.m.	4 0 p.m.
No. of Experiment	*a*	*b*	*c* ‡	1	2	3
Condition of Mine	Return Airway to Ventilator closed.		Return Airway to Ventilator closed, with exception of Opening of 3 sq. feet, Air being drawn from Mine.	Mine under ordinary working conditions.		
Temperature, atmosphere, wet, degs. Fahr. ..	57¾	57¾	58	52½	52¾	52½
„ „ dry, „ ..	57¾	57¾	58¾	55	55½	55
„ in fan drift, wet, „ ..	89	89	88	87	90	92
„ „ dry, „ ..	89	89	88	87	90	92
„ bottom of pit, „ ..	*	*	*	71	72	72½
Pressure of atmosphere, inches of mercury ..	29·19	29·18	29·17	29·22	29·24	29·22
Results of Observations:—						
Duration of experiment, minutes	8	8	6	8	8	8
Mean revolutions of engine, per minute	12·625	26·125	25·333	45·375	17·875	26·375
„ „ fan, per minute	30·474	63·060	61·149	109·525	43·146	63·663
„ „ anemometer, per minute ..	*	*	‡	1,616·62	756·62	1,116·75
Water-gauge:—						
Mean depression, at inlet of fan, No. I., inches	*	*	*	5·556	0·933	1·876
„ „ fan drift, 18† feet from fan, No. II., inches..	*	2·000	2·000	5·526	0·922	1·827
„ „ inside fan, No. IV., inches	*	*	*	*	*	*
„ „ 16 feet below Guibal drift, No. V., inches..	*	*	*	5·305	0·821	1·827
„ „ bottom of shaft, No. III., inches	*	*	*	4·750	1·150	1·815
Indicator Diagrams:—						
Mean pressure, pounds per square inch:—						
Right-hand engine, back end	(1) 1·20	(18) 1·04	..	(33) 14·00	(36) 3·24	(27) 5·41
„ „ „	(2) 0·77	(19) 1·86	..	(34) 14·13	(37) 2·93	(28) 5·05
„ „ „	(3) 0·93	(20) 2·09	..	(35) 14·06	(38) 3·18	(29) 5·14
„ „ „ average ..	0·96	1·66	..	14·06	3·12	5·20
„ „ front end	(1) 0·90	(18) 1·15	..	(33) 14·18	(36) 4·01	(27) 5·79
„ „ „	(2) 0·69	(19) 1·82	..	(34) 14·29	(37) 3·71	(28) 5·58
„ „ „	(3) 1·74	(20) 2·19	..	(35) 14·41	(38) 4·14	(29) 5·72
„ „ „ average ..	1·11	1·72	..	14·29	3·95	5·69
„ „ average	(1) 1·05	(18) 1·10	..	(33) 14·06	(36) 3·62	(27) 5·60
„ „ „	(2) 0·73	(19) 1·84	..	(34) 14·21	(37) 3·32	(28) 5·31
„ „ „	(3) 1·33	(20) 2·14	..	(35) 14·23	(38) 3·66	(29) 5·43
Left-hand engine, back end	(1) 0·75	(18) 1·38	..	(33) 12·72	(36) 2·04	(27) 4·83
„ „ „	(2) 0·75	(19) 1·55	..	(34) 12·76	(37) 2·33	(28) 5·22
„ „ „	(3) 0·59	(20) 1·74	..	(35) 13·73	(38) 2·26	(29) 5·15
„ „ „ average ..	0·70	1·56	..	13·07	2·21	5·07
„ „ front end	(1) 2·29	(18) 1·66	..	(33) 12·66	(36) 3·06	(27) 5·14
„ „ „	(2) 3·18	(19) 1·12	..	(34) 13·06	(37) 3·28	(28) 4·78
„ „ „	(3) 2·06	(20) 2·08	..	(35) 12·76	(38) 3·09	(29) 4·35
„ „ „ average ..	2·51	1·62	..	12·83	3·14	4·76
„ „ average	(1) 1·52	(18) 1·52	..	(33) 12·69	(36) 2·55	(27) 4·99
„ „ „	(2) 1·97	(19) 1·33	..	(34) 12·91	(37) 2·80	(28) 5·00
„ „ „	(3) 1·32	(20) 1·91	..	(35) 13·25	(38) 2·68	(29) 4·75
Right and left-hand engines, average.. ..	1·32	1·64	..	13·56	3·10	5·18
Steam pressure, pounds per square inch	Nil.	50	52	34	33	42
Vacuum, pounds per square inch	*	13	12	12	12	12
Results of Calculations:—						
Weight of cubic foot of air of atmosphere, pound	0·07443	0·07443	0·07425	0·07517	0·07498	0·07517
„ „ „ fan drift „	0·06944	0·06944	0·06954	0·06983	0·06940	0·07209
„ „ water, pounds	62·378	62·378	62·373	62·391	62·389	62·391
Temperature of water, degs. Fahr.	57¾	57¾	58¾	55	55½	55
Mean velocity of air, feet per minute	..	..	..	1,562	753	1,098
Velocity of circumference of fan, feet per minute	2,872·1	5943·2	5763·1	10,322·5	4066·4	6,000
Mean volume of air, cubic feet per minute ..	..	..	..	134,566	64,871	94,592
At normal velocity, volume of air, cubic feet per minute	..	..	..	78,214	95,680	94,592
„ „ depression at inlet, inches ..	..	..	..	1·677	2·030	1·876
„ „ „ fan drift, inches	..	2·038	2·167	1·867	2·006	1·827
„ „ theoretical depression, inches	4·297	4·298	4·296	4·331	4·313	4·307
Manometric efficiency, at inlet of fan, per cent.	..	..	..	43·33	47·07	43·55
„ „ fan drift, per cent. ..	..	47·41	50·44	43·10	46·51	42·42
Useful effect in air, at inlet of fan, horse-power ..	..	..	..	117·78	9·53	27·95
„ „ „ fan drift, „ ..	..	..	..	117·15	9·42	27·22
Motive power of engine, horse-power	6·31	16·23	..	233·04	20·99	51·75
„ utilized, at inlet of fan, per cent..	..	..	..	50·50	45·40	54·00
„ „ fan drift, per cent. ..	..	..	..	50·2	44·8	52·6
Equivalent orifice of mine:—						
Inlet water-gauge, square feet	..	..	..	21·55	25·24	26·04
Drift „ „ .. .	..	..	..	21·59	25·46	26·37

* No observation recorded. † The water-gauge was situated 25 feet from inlet of Guibal fan.
‡ Anemometer failed, owing to excessive velocity of air, when passing through opening of 3 square feet.

RESULTS OF EXPERIMENTS ON THE GUIBAL AND WADDLE FANS.

Guibal.								
. 27 p.m.	Oct. 27 3 16 p.m.	Oct 28 9 50 a.m.	Oct. 27 4 46 p.m.	Oct. 28 10 27 a.m.	Oct. 27 5 15 p.m.	Oct. 28 5 7 p.m.	Oct. 28 5 40 p.m.	Oct. 28 6 0 p.m.
a	b	1	2	3	4	c	d	e§
eturn Airway o Ventilator closed.		Return Airway to Ventilator closed, with exception of Opening of 3 sq. feet.		Return Airway to Ventilator closed, with exception of Opening of 6 sq. feet.		Mine under ordinary working conditions.	Entrance of Air facilitated by opening Separation-doors at Bottom of Pit.	Air admitted freely from Atmosphere, by opening Doors on Surface.
		Air being drawn from Atmosphere.	Air being drawn from Mine.	Air being drawn from Atmosphere.	Air being drawn from Mine.			
61	61	58	61½	58½	61½	59	58½	*
62	62	62	62	62	61½	60	60	*
91	91	91	91½	89½	93½	88	86	*
91	91	91	91½	89½	93½	88	86	*
*	-	*	*	*	*	72½	69	*
·28	29·28	29·21	29·28	29·20	29·28	29·16	29·15	*
8	8	8	8	8	8	8	8	*
·375	62·875	64·250	63·250	64·000	64·125	62·500	64·625	§
375	62·875	64·250	63·250	64·000	64·125	62·500	64·625	*
*	*	148·00	180·50	343·00	378·00	802·37	1232·00	*
*	2·650	2·600	2·600	2·600	2·525	*	*	*
*	*	2·600	2·600	2·583	2·550	2·450	2·094	*
075	2·850	2·835	2·850	2·836	2·800	2·708	2·773	*
	*	*	*	*	*	2·513	1·861	*
*	*	*	*	*	*	2·(0)	*	*
1·45	(4) 10·40	(12) 10·54	(7) 10·30	(15) 11·34	(9) 11·42	(21) 17·34	(24) 27·04	*
1·82	(5) 10·10	(13) 9·39	(8) 11·96	(16) 12·67	(10) 13·12	(22) 18·28	(25) 26·14	*
1·97	(6) 9·70	(14) 8·32	..	(17) 12·48	(11) 12·08	(23) 19·52	(26) 24·94	*
1·75	10·07	9·42	11·13	12·16	12·21	18·38	26·04	*
2·41	(4) 9·60	(12) 11·27	(7) 11·54	(15) 12·21	(9) 13·02	(21) 20·24	(24) 25·40	*
2·28	(5) 10·00	(13) 11·32	(8) 11·50	(16) 12·80	(10) 12·50	(22) 20·82	(25) 24·72	*
2·37	(6) 10·64	(14) 12·61	..	(17) 13·22	(11) 12·56	(23) 21·94	(26) 24·98	*
2·35	10·08	11·73	11·52	12·74	12·69	21·00	25·03	*
1·93	(4) 10·00	(12) 10·90	(7) 10·92	(15) 11·77	(9) 12·22	(21) 18·79	(24) 26·22	*
2·05	(5) 10·05	(13) 10·36	(8) 11·73	(16) 12·74	(10) 12·81	(22) 19·55	(25) 25·43	*
2·17	(6) 10·17	(14) 10·46	..	(17) 12·85	(11) 12·32	(23) 20·73	(26) 24·96	*
..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..
..	.	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..
..	..	.	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..
2·05	10·07	10·57	11·32	12·45	12·45	19·69	25·54	..
36	39	36	38	36	40	39	42	..
-	*	*	*	*	*	*	*	..
·0740	0·0740	0·07391	0·07407	0·07387	0·07407	0·07403	0·07401	..
·0693	0·0693	0·06917	0·06925	0·06937	0·06891	0·06953	0·06981	..
2·355	62·355	62·355	62·355	62·355	62·359	62·366	62·366	..
62	62	62	62	62	61⅞	60	60	..
..	..	154·75	183	346·0	381	797⅞	1,206	..
1166·2	5925·6	6,055·2	5,961	6,031·8	6,043·2	5890·5	6,090·6	..
..	..	17,372	20,880	39,842	42,771	89,513	135,385	..
..	..	17,212	21,015	38,635	42,460	91,174	133,363	..
..	2·716	2·552	2·633	2·572	2·488	..	..	..
1·985	..	2·552	2·633	2·556	2·513	2·541	2·032	..
4·283	4·283	4·276	4·283	4·281	4·273	4·290	4·298	..
..	63·41	59·68	61·47	60·08	58·22	..	..	..
..	..	59·68	61·47	59·71	58·81	59·23	47·28	..
..	..	7·11	8·54	15·90	17·00	..	..	..
..	..	7·11	8·54	15·79	17·17	34·53	44·64	..
1·37	34·29	33·79	38·77	43·16	43·24	65·66	89·41	..
.	..	19·32	22·02	36·83	39·31	..	..	..
..	..	19·32	22·02	36·58	39·73	51·80	49·92	..
..	..	4·04	4·86	9·03	10·09	..	..	..
..	..	4·04	4·86	9·07	10·05	21·49	35·14	..

§ Experiment abandoned owing to heating of the crank-pin of engine.

APPENDIX B.—TABLES 1 AND 2.—CWMAMAN COLLIERY.—Vidimus of Experiments on the Guibal and Waddle Fans, October 27th, 28th and 29th, 1888.

Guibal Fan, 30 Feet in Diameter.

Number of Experiment.	Condition of Mine.	Engine.			Fan.		Air.			Water-gauge, where Air was measured.	Horse-power in the Air.	Percentage of Power utilized.	Temperatures.					Barometer in Air.	Water-gauge at Pit-bottom.
		Revolutions per Minute.	Mean Steam-pressure on Piston.	Horse-power.	Revolutions per Minute.	Speed of Periphery per Minute.	Velocity per Minute.	Volume per Minute.	Volume per Revolution.				Bank.		Fan-drift.		Pit-bottom.		
													Wet.	Dry.	Wet.	Dry.			
			Lbs. per Sq. In.			Feet.	Feet.	Cubic Feet.	Cubic Feet.	Inches.			Degs.	Degs.	Degs.	Degs.	Degs.	Inches.	Inches.
a	Friction of engine	12⅜	2·05	1·4	12·37	1,166	*	*	*	0·07	*	*	61	62	91	91	*	29·28	*
b	Return airway closed	62⅞	10·07	34·3	62·87	5,926	*	*	*	†12·65	*	*	61	62	91	91	*	29·28	*
2	Opening of 3 square feet	63¼	11·32	38·8	63·25	5,961	186	20,880	330	2·60	8·5	22·0	61¼	62	91¼	91½	*	29·28	*
1	„ 3 „	64¼	10·57	36·8	64·25	6,055	155	17,372	271	2·60	7·1	19·3	58	62	91	91	*	29·21	*
3	„ 6 „	64	12·45	43·2	64·00	6,032	316	38,842	607	2·58	15·7	36·6	58½	62	89½	89½	*	29·20	*
4	„ 6 „	64⅛	12·45	43·2	64·12	6,043	381	42,771	667	2·55	17·2	39·7	61¼	61⅝	93½	93½	*	29·28	*
c	Under ordinary conditions ..	62½	19·69	66·7	62·50	5,891	797	89,513	1,432	2·45	34·5	51·8	59	60	88	88	72¼	29·16	2·00
d	Separation-doors opened	64⅝	25·54	89·4	64·62	6,091	1,206	135,385	2,096	2·09	44·6	49·9	58½	60	86	86	69	29·15	*
e	Air admitted freely	Experiment not completed, owing to heating of crank-pin of engine.																	
Waddle Fan, 30 Feet in Diameter.																			
a	Friction of engine	12⅜	1·32	6·3	30·47	2,872	*	*	*	*	*	*	57¾	57¾	89	89	*	29·19	*
b	Return airway closed	26⅝	1·64	16·2	63·06	5,943	*	*	*	2·00	*	*	57¾	57¾	89	89	*	29·18	*
c	Opening of 3 square feet	25⅓	*	*	61·15	5,763	Anemometer failed.			2·00	*	*	58	58¾	88	88	*	29·17	*
2	Under ordinary conditions	17⅞	3·10	20·9	43·15	4,066	753	64,871	1,503	0·92	9·4	44·8	52¾	55⅛	90	90	72	29·24	1·15
3	„ „	26⅝	5·18	51·7	63·66	6,000	1,098	94,592	1,486	1·83	27·2	52·6	52½	55	92	92	72½	29·22	1·81
1	„ „ .. .	45⅝	13·56	233·0	109·53	10,323	1,562	134,566	1,227	5·53	117·1	50·2	52½	55	87	87	71	29·22	4·75
4	Separation-doors opened	26⅝	7·18	72·7	64·57	6,085	1,643	141,544	2,192	1·82	40·4	55·6	52	55	86	86	68	29·22	*

* No observation recorded. † Water-guage at fan-inlet.

APPENDIX B.—TABLE 3.—EXPERIMENTS OF JUNE 2ND, 1889, UPON THE GUIBAL FAN AT GREAT WESTERN COLLIERY.

Dimensions, etc., of the Fan.

Description	centrifugal fan of Guibal type.
Diameter	40 feet.
Width, at inlet	12 „
„ at periphery	12 „
Diameter of inlet	14 „

Normal velocity (6,000 feet per minute =) 47·74 revolutions per minute.

Dimensions, etc., of the Engine.

Number of cylinders	one.
Diameter of the piston	36 inches.
„ of piston-rod, fore end	4½ „
Mean effective area of the piston	1009·02 square inches.
Stroke of piston	36 „
Ratio of transmission	direct, as one to one.

Sundry Particulars.

Area of place of measurement (Fig. 8, Plate XV.) ... 102·37 square feet.

APPENDIX B.—TABLE 3.—GREAT WESTERN COLLIERY.–

Type of Ventilator	Guibal.			
Date .. 1889	June 2	June 2	June 2	Ju[illegible]
Time	12 37 p.m.	1 0 p.m.	2 49 p.m.	4 [illegible]
No. of Experiment	1	2	3	4
Condition of Mine	Mine under ordinary working conditions.	Return Airway to Ventilator closed.	Return Airway to Ventilator closed, with exception of Opening 3 sq. feet.	
			Air being drawn from Mine.	Air b[illegible] drawn fr[illegible] Atmosp[illegible]
Temperature, atmosphere, wet, degs. Fahr.	60	60	61½	[illegible]
,, ,, dry, ,,	61½	62	63½	[illegible]
,, in fan drift, wet, ,,	61½	63	64½	[illegible]
,, ,, dry, ,,	63	64½	66½	[illegible]
Pressure of atmosphere, inches of mercury	29·185	29·19	29·19	[illegible]
Results of Observations:—				
Duration of experiment, minutes	8	8	8	[illegible]
Mean revolutions of engine, per minute	6½	47½	47⅞	[illegible]
,, ,, fan, per minute	6½	47½	47⅞	[illegible]
,, ,, anemometer per minute	3½	219⅝	338⅞	[illegible]
Water-gauge:—				
Mean depression, at inlet of fan, No. I., inches	0·05	2·58	2·54	[illegible]
,, ,, fan drift, 40 feet from fan No. II., inches	0·00	−0·01	0·00	[illegible]
Indicator Diagrams.—				
Mean pressure, pounds per square inch:—				
Back end	(1) 2·124	(4) 9·569	(7) 9·082	(16) [illegible]
,,	(2) 2·079	(5) 9·568	(8) 10·639	(17) [illegible]
,,	(3) 2·165	(6) 9·809	(9) 9·952	(18) [illegible]
,, average	2·123	9·649	9·891	[illegible]
Front end	(1) 2·256	(4) 11·760	(7) 12·268	(16) [illegible]
,,	(2) 2·878	(5) ..	(8) 11·594	(17) [illegible]
,,	(3) 2·418	(6) ..	(9) 11·900	(18) [illegible]
,, average	2·517	11·760	11·897	[illegible]
Average	(1) 2·190	(4) 10·664	(7) 10·675	(16) [illegible]
,,	(2) 2·478	(5) 9·568	(8) 11·082	(17) 11[illegible]
,,	(3) 2·292	(6) 9·809	(9) 10·926	(18) 11[illegible]
,, average	2·320	10·013	10·894	11[illegible]
Steam pressure, pounds per square inch	51	50	50	54
Results of Calculations:—				
Weight of cubic foot of air of atmosphere, pound	0·07386	0·07381	0·07343	0·0[illegible]
,, ,, ,, fan drift, ,,	0·07363	0·07341	0·07315	0·0[illegible]
,, ,, water, pounds	62·358	62·355	62·344	62·3[illegible]
Temperature of water, degs. Fahr.	61½	62	63½	63
Mean velocity of air, feet per minute	23½	225	342	[illegible]
Velocity of circumference of fan, feet per minute	848·23	5,937·62	5,953·33	6,016·[illegible]
Mean volume of air, cubic feet per minute	2,406	23,033	35,011	36,[illegible]
At normal velocity, volume of air, cubic feet per minute	16,572	23,271	35,280	[illegible]
,, ,, depression at inlet, inches	2·501	2·633	2·579	[illegible]
,, ,, ,, fan drift, inches	..	..	1·015	[illegible]
,, ,, theoretical depression, ,,	4·407	4·400	4·381	[illegible]
Manometric efficiency, at inlet of fan, per cent.	56·75	59·84	58·86	[illegible]
,, ,, fan drift, ,,	..	..		
Useful effect in air, at inlet of fan, horse-power	0·019	9·356	13·999	[illegible]
,, ,, fan drift, ,,	0·000	..	0·000	
Motive power of engine, horse-power	2·86	88·21	94·68	[illegible]
,, utilized, at inlet of fan, per cent.	0·70	10·60	14·78	[illegible]
,, ,, fan drift, ,,	0·00	..	0·000	..
Equivalent orifice of mine:—				
Inlet water-gauge, square feet	4·085	5·459	8·352	[illegible]
Drift ,, ,,	..	..	..	

RESULTS OF EXPERIMENTS ON THE GUIBAL FAN.

<table>
<tr><th colspan="7">GUIBAL.</th></tr>
<tr><th>June 2
3 6 p.m.</th><th>June 2
3 43 p.m.</th><th>June 2
6 27 p.m.</th><th>June 2
5 43 p.m.</th><th>June 2
7 0 p.m.</th><th>June 2
5 21 p.m.</th><th>June 2
7 27 p.m.</th></tr>
<tr><th>5</th><th>6</th><th>7</th><th>8 ‡</th><th>9</th><th>10</th><th>11</th></tr>
<tr><th colspan="2">Return Airway to Ventilator closed, with exception of Openin of 6 sq. feet.</th><th colspan="2" rowspan="2">Mine under ordinary working conditions.</th><th rowspan="2">Entrance of Air facilitated by opening Separation-doors at Bottom of Pit.</th><th rowspan="2">Mine under ordinary working conditions.</th><th rowspan="2">Air admitted freely from Atmosphere, by opening Doors on Surface.</th></tr>
<tr><th>Air being drawn from Mine.</th><th>Air being drawn from Atmosphere.</th></tr>
<tr><td>61</td><td>60½</td><td>58</td><td>59</td><td>58½</td><td>59½</td><td>57½</td></tr>
<tr><td>64</td><td>64½</td><td>61½</td><td>62¾</td><td>61½</td><td>63½</td><td>62</td></tr>
<tr><td>64¾</td><td>64½</td><td>63½</td><td>63¾</td><td>63</td><td>63</td><td>60½</td></tr>
<tr><td>67¾</td><td>67</td><td>65</td><td>64½</td><td>64½</td><td>64</td><td>62½</td></tr>
<tr><td>29·19</td><td>29·185</td><td>29·183</td><td>29·18</td><td>29·185</td><td>29·185</td><td>29·20</td></tr>
<tr><td>8</td><td>8</td><td>8</td><td>8</td><td>8</td><td>8</td><td>8</td></tr>
<tr><td>48</td><td>48</td><td>50⅞</td><td>46⅝</td><td>46⅞</td><td>33¾</td><td>41⅝</td></tr>
<tr><td>48</td><td>48</td><td>50⅞</td><td>46⅝</td><td>46⅞</td><td>33¾</td><td>41⅝</td></tr>
<tr><td>502⅝</td><td>526</td><td>2,323⅛</td><td>2,168⅝</td><td>2,251⅛</td><td>1,627¾</td><td>3,689¼</td></tr>
<tr><td>2·59</td><td>2·57</td><td>2·94</td><td>2·44</td><td>2·49</td><td>1·29</td><td>1·55</td></tr>
<tr><td>0·01</td><td>−0·02</td><td>2·23</td><td>1·85</td><td>1·79</td><td>0·90</td><td>0·42</td></tr>
<tr><td>(10) 10·524</td><td>(13) 10·490</td><td>(25) 19·150</td><td>(22) 15·713</td><td>(28) 16·500</td><td>(19) 10·335</td><td>(31) 19·461</td></tr>
<tr><td>(11) 10·564</td><td>(14) 10·487</td><td>(26) 19·100</td><td>(23) 16·033</td><td>(29) 17·214</td><td>(20) 10·285</td><td>(32) 20·017</td></tr>
<tr><td>(12) 10·370</td><td>(15) 10·678</td><td>(27) 19·289</td><td>(24) 15·514</td><td>(30) 17·228</td><td>(21) 11·243</td><td>(33) 19·658</td></tr>
<tr><td>10·486</td><td>10·552</td><td>19·179</td><td>15·783</td><td>16·981</td><td>10·621</td><td>19·712</td></tr>
<tr><td>(10) 12·125</td><td>(13) 13·192</td><td>(25) 21·300</td><td>(22) 18·285</td><td>(28) 20·098</td><td>(19) 12·176</td><td>(31) 22·004</td></tr>
<tr><td>(11) 12·301</td><td>(14) 12·375</td><td>(26) 21·921</td><td>(23) 18·534</td><td>(29) 19·721</td><td>(20) 11·975</td><td>(32) 23·721</td></tr>
<tr><td>(12) 12·923</td><td>(15) 12·853</td><td>(27) 22·218</td><td>(24) 18·415</td><td>(30) 19·524</td><td>(21) 12·225</td><td>(33) 22·977</td></tr>
<tr><td>12·449</td><td>12·807</td><td>21·813</td><td>18·411</td><td>19·781</td><td>12·125</td><td>22·901</td></tr>
<tr><td>(10) 11·324</td><td>(13) 11·841</td><td>(25) 20·225</td><td>(22) 17·000</td><td>(28) 18·300</td><td>(19) 11·255</td><td>(31) 20·732</td></tr>
<tr><td>(11) 11·432</td><td>(14) 11·432</td><td>(26) 20·511</td><td>(23) 17·284</td><td>(29) 18·467</td><td>(20) 11·130</td><td>(32) 21·868</td></tr>
<tr><td>(12) 11·646</td><td>(15) 11·765</td><td>(27) 20·753</td><td>(24) 16·966</td><td>(30) 18·376</td><td>(21) 11·734</td><td>(33) 21·318</td></tr>
<tr><td>11·467</td><td>11·679</td><td>20·496</td><td>17·083</td><td>18·381</td><td>11·373</td><td>21·306</td></tr>
<tr><td>51</td><td>50</td><td>53</td><td>49</td><td>53</td><td>50</td><td>53</td></tr>
<tr><td>0·07354</td><td>0·07348</td><td>0·07390</td><td>0·07378</td><td>0·07390</td><td>0·07361</td><td>0·07390</td></tr>
<tr><td>0·07295</td><td>0·07304</td><td>0·07330</td><td>0·07337</td><td>0·07339</td><td>0·07346</td><td>0·07374</td></tr>
<tr><td>62·342</td><td>62·339</td><td>62·358</td><td>62·353</td><td>62·358</td><td>62·346</td><td>62·355</td></tr>
<tr><td>64</td><td>64½</td><td>61½</td><td>62½</td><td>61½</td><td>63½</td><td>62</td></tr>
<tr><td>503½</td><td>526½</td><td>2,189</td><td>2,055½</td><td>2,127½</td><td>1,571</td><td>3,309·75</td></tr>
<tr><td>6,031·87</td><td>6,031·87</td><td>6,393·15</td><td>5,859·08</td><td>5,890·50</td><td>4,241·16</td><td>5,199·34</td></tr>
<tr><td>51,543</td><td>53,898</td><td>224,088</td><td>210,396</td><td>217,792</td><td>160,823</td><td>338,819</td></tr>
<tr><td>51,263</td><td>53,606</td><td>210,279</td><td>215,427</td><td>221,811</td><td>227,487</td><td>390,941</td></tr>
<tr><td>2·562</td><td>2·542</td><td>2·588</td><td>2·558</td><td>2·582</td><td>2·581</td><td>2·063</td></tr>
<tr><td>0·009</td><td>..</td><td>1·963</td><td>1·939</td><td>1·856</td><td>1·800</td><td>0·559</td></tr>
<tr><td>4·378</td><td>4·380</td><td>4·399</td><td>4·398</td><td>4·401</td><td>4·396</td><td>4·412</td></tr>
<tr><td>58·52</td><td>58·03</td><td>58·83</td><td>58·16</td><td>58·66</td><td>58·71</td><td>46·75</td></tr>
<tr><td>..</td><td>..</td><td>44·62</td><td>44·08</td><td>42·17</td><td>49·94</td><td>12·67</td></tr>
<tr><td>21·106</td><td>21·806</td><td>103·734</td><td>80·831</td><td>85·387</td><td>32·659</td><td>82·690</td></tr>
<tr><td>..</td><td>..</td><td>78·682</td><td>61·286</td><td>61·383</td><td>22·785</td><td>22·406</td></tr>
<tr><td>100·99</td><td>102·84</td><td>191·29</td><td>146·12</td><td>158·07</td><td>70·41</td><td>161·72</td></tr>
<tr><td>20·80</td><td>21·20</td><td>54·22</td><td>55·32</td><td>54·02</td><td>46·38</td><td>51·13</td></tr>
<tr><td>..</td><td>..</td><td>41·13</td><td>41·94</td><td>38·83</td><td>32·36</td><td>13·85</td></tr>
<tr><td>12·166</td><td>12·776</td><td>49·712</td><td>51·301</td><td>52·526</td><td>53·834</td><td>103·898</td></tr>
<tr><td>..</td><td>..</td><td>57·079</td><td>58·830</td><td>61·978</td><td>64·504</td><td>199·503</td></tr>
</table>

‡ This experiment was made, under the same conditions, for comparison with No. 7 experiment upon the Schiele fan (Table 4).

APPENDIX B.—TABLE 3.—GREAT WESTERN COLLIERY.—VIDIMUS OF EXPERIMENTS ON THE GUIBAL FAN, 40 FEET IN DIAMETER. JUNE 2ND, 1889.

Number of Experiment.	Condition of Mine.	Engine.			Fan.		Air.			Water-gauge, where Air was measured.	Horse-power in the Air.	Percentage of Power utilized.	Temperatures.					Barometer in Air.	Water-gauge at Pit-bottom.
		Revolutions per Minute.	Mean Steam-pressure on Piston.	Horse-power.	Revolutions per Minute.	Speed of Periphery per Minute.	Velocity per Minute.	Volume per Minute.	Volume per Revolution.				Bank.		Fan-drift.		Pit-bottom.		
													Wet.	Dry.	Wet.	Dry.			
			Lbs. per Sq. In.			Feet.	Feet.	Cubic Feet.	Cubic Feet.	Inches.			Degs.	Degs.	Degs.	Degs.	Degs.	Inches.	Inches.
1	Friction of engine	6¾	2·32	2·9	6·75	848	23	2,406	356	†0·05	0·0	0·0	60	61½	61½	63	*	29·18	*
2	Return airway closed	47¼	10·13	88·2	47·25	5,938	225	23,033	487	†2·58	9·3	10·6	60	62	63	64½	*	29·19	*
3	Opening of 3 square feet	47⅜	10·89	94·7	47·37	5,953	342	35,011	739	†2·54	14·0	14·8	61½	63¾	64½	66¼	*	29·19	*
4	" 3 "	47⅞	11·22	98·5	47·87	6,016	377	38,517	805	†2·59	15·7	15·9	59½	63	64	66¾	*	29·18	*
5	" 6 "	48	11·47	100·9	48·00	6,032	503	51,543	1,074	†2·59	21·1	20·8	61	64	64¾	67¾	*	29·19	*
6	" 6 "	48	11·68	102·8	48·00	6,032	526	53,898	1,123	†2·57	21·8	21·2	60½	64½	64½	67	*	29·18	*
10	Under ordinary conditions	33¾	11·37	70·4	33·75	4,241	1,571	160,823	4,765	0·90	22·8	32·3	59½	63½	63	64	*	29·18	*
8	" " "	46⅝	17·08	145·1	46·62	5,859	2,055	210,396	4,512	1·85	61·3	41·9	59	62¾	63¼	64½	*	29·18	*
7	" " "	50⅞	20·49	191·3	50·87	6,393	2,189	224,088	4,404	2·23	78·7	41·1	58	61½	63½	65	*	29·18	*
9	Separation-doors opened	46⅞	18·38	158·1	46·87	5,890	2,127	217,792	4,646	1·79	61·4	38·8	58½	61½	63	64½	*	29·18	*
11	Air admitted freely	41⅜	21·31	161·7	41·37	5,199	3,310	338,819	8,187	0·42	22·4	13·8	57½	62	60½	62½	*	29·20	*

* No observation recorded. † Water-gauge at fan-inlet.

APPENDIX B.—TABLE 4.—EXPERIMENTS OF JUNE 3RD, 1889, UPON THE SCHIELE FAN AT GREAT WESTERN COLLIERY.

DIMENSIONS, ETC., OF THE FAN.

Description	centrifugal fan of Schiele type.
Diameter	15 feet 3 inches.
Width, at inlet	6 „ 0 „
„ at periphery	3 „ 9 „
Diameter of inlet	8 „ 8 „

Normal velocity (6,000 feet per minute =)125·23 revolutions per minute.

DIMENSIONS, ETC., OF THE ENGINE.

Number of cylinders	one.
Diameter of the piston	32 inches.
„ of piston-rod, fore end	5 „
Mean effective area of the piston	795·39 square „
Stroke of piston	36 „
Ratio of transmssion	by belting, about 3·2 to one.

SUNDRY PARTICULARS.

Area of place of measurement (Fig. 9, Plate XV.)...162·75 square feet.

APPENDIX B.—TABLE 4.—GREAT WESTERN COLLIERY.

Type of Ventilator	SCHIELE.		
Date 1889	June 3	June 3	June 3
Time	11 16 a.m.	1 15 p.m.	11 56 a.m.
No. of Experiment	1	2	3
Condition of Mine	Return Airway to Ventilator closed.	Return Airway to Ventilator closed, with exception of Opening of 3 sq. feet.	
		Air being drawn from Atmosphere.	Air being drawn from Mine.
Temperature, atmosphere, wet, degs. Fahr. ..	51½	62	58
,, ,, dry, ,, ..	61	67	62¼
,, in fan drift, wet, ,, ..	62	64½	61¾
,, ,, dry, ,, ..	62¼	65	63
Pressure of atmosphere, inches of mercury ..	29·38	29·40	29·385
Results of Observations:—			
Duration of experiment, minutes	8	8	8
Mean revolutions of engine, per minute	36⅛	38⅜	42⅜
,, ,, fan, per minute	112⅝	121⅞	133⅞
,, ,, anemometer, per minute ..	140⅝	197⅞	218⅝
Water-gauge:—			
Mean depression, at inlet of fan, No. I., inches	1·67	1·97	2·24
,, ,, fan drift, 108 feet from fan, No. II., inches	– 0·21	– 0·05	– 0·10
Indicator Diagrams:—			
Mean pressure, pounds per square inch:—			
Back end	(37) 5·068	(49) 6·310	(40) 7·139
,, ...	(38) 4·521	(50) 5·963	(41) 6·680
,, ...	(39) 5·128	(51) 6·646	(42) 6·765
,, average	4·906	6·306	6·861
Front end	(37) 7·055	(49) 6·871	(40) 8·163
,, ...	(38) 5·720	(50) 6·554	(41) 7·950
,, ...	(39) 5·606	(51) 7·266	(42) 8·920
,, average	6·127	6·897	8·344
Average	(37) 6·062	(49) 6·591	(40) 7·651
,, ...	(38) 5·120	(50) 6·259	(41) 7·315
,, ...	(39) 5·368	(51) 6·956	(42) 7·843
,, average	5·517	6·602	7·603
Steam pressure, pounds per square inch	52	54	53
Results of Calculations:—			
Weight of cubic foot of air of atmosphere, pound	0·07463	0·07364	0·07429
,, ,, ,, fan drift, ,,	0·07416	0·07381	0·07413
,, ,, water, pounds	62·361	62·322	62·351
Temperature of water, degs. Fahr.	61	67	62¼
Mean velocity of air, feet per minute	147	203¼	223¾
Velocity of circumference of fan, feet per minute	5,407·77	5,838·95	6,407·88
Mean volume of air, cubic feet per minute ..	23,924	33,079	36,415
At normal velocity, volume of air, cubic feet per minute	26,542	33,989	34,095
,, ,, depression at inlet, inches ..	2·055	2·079	1·963
,, ,, ,, fan drift, inches	..	..	..
,, ,, theoretical depression, inches	4·446	4·409	4·436
Manometric efficiency, at inlet of fan, per cent.	46·08	47·15	44·25
,, ,, fan drift, per cent. ..	..	..	..
Useful effect in air, at inlet of fan, horse-power	6·290	10·254	12·843
,, ,, fan drift, ,,	..	..	..
Motive power of engine, horse-power	28·82	36·88	46·59
,, utilized, at inlet of fan, per cent. ..	21·82	27·80	27·56
,, ,, fan drift, per cent. ..	..	..	..
Equivalent orifice of mine:—			
Inlet water-gauge, square feet	7·081	8·975	9·292
Drift ,, ,, ...	..	..	..

RESULTS OF EXPERIMENTS ON THE SCHIELE FAN.

SCHIELE.

ne 3	June 3	June 3	June 3	June 3	June 3	June 3	June 3
15 p.m.	10 53 a.m.	2 18 p.m.	2 46 p.m.	2 1 p.m.	4 15 p.m.	1 42 p.m.	4 34 p.m.
5	a	6	7†	8	9	10	11
rn Air- o Venti- closed, excep- of Open- of 6 sq. eet. being rn from line.	Mine under ordinary working conditions.				Entrance of Air facilitated by opening Separation-doors at Bottom of Pit.	Mine under ordinary working conditions.	Air admitted * freely from Atmosphere, by opening Doors on Surface.
58½	55½	59	58½	61½	57	62	56½
63	60½	66½	66½	66	65	66½	69½
62½	59	63½	63	63	62½	62½	58
63	59½	65	64	63	63	63	61½
9·39	29·365	29·42	29·44	29·415	29·45	29·41	29·45
8	8	8	8	8	8	8	8
39¼	6⅝	54⅞	44⅜	38¼	39⅜	26⅜	42⅜
124	20⅞	171⅜	139¾	120¾	124¾	83¾	133¾
271¾	33⅜	1,478⅜	1,210⅜	1,105⅜	1,173⅜	781¾	2,072⅜
1·99	0·02‡	3·84	2·53	1·87	2·02	0·90	1·57
0·05	− 0·23	3·04	1·99	1·41	1·52	0·66	0·44
) 6·686	(34) 2·907	(58) 25·910	(61) 19·622	(55) 13·045	(64) 10·967	(52) 7·636	(67) 23·611
) 6·788	35) 2·469	(59) 25·567	(62) 19·934	(56) 17·220	(65) 20·669	(53) 7·652	(68) 23·807
) 6·147	(36) 3·112	(60) 25·567	(63) 19·466	(57) 16·100	(66) 16·032	(54) 7·503	(69) 23·414
6·540	2·829	25·681	19·674	15·455	15·889	7·597	23·611
) 7·721	(34) 3·173	(58) 26·672	(61) 20·714	(55) 14·459	(64) 21·458	(52) 8·844	(67) 24·824
) 8·163	(35) 3·492	(59) 27·491	(62) 20·816	(56) 18·903	(65) 18·060	(53) 8·850	(68) 25·242
) 8·130	(36) 3·062	(60) 27·582	(63) ..	(57) 18·589	(66) 18·219	(54) 8·826	(69) 25·217
8·005	3·242	27·248	20·765	17·317	19·246	8·840	25·094
) 7·205	(34) 3·040	(58) 26·291	(61) 20·167	(55) 13·752	(64) 16·211	(52) 8·241	(67) 24·217
) 7·474	(35) 2·981	(59) 26·530	(62) 20·376	(56) 18·062	(65) 19·365	(53) 8·251	(68) 24·525
) 7·139	(36) 3·088	(60) 26·574	(63) 19·466	(57) 17·345	(66) 17·125	(54) 8·165	(69) 24·316
7·273	3·036	26·465	20·110	16·386	17·567	8·219	24·352
52	54	53	53	54	53	54	54
07425	0·07456	0·07385	0·07391	0·07381	0·07416	0·07374	0·07359
07406	0·07460	0·07390	0·07410	0·07381	0·07427	0·07417	0·07459
2·349	62·364	62·325	62·325	62·329	62·335	62·325	62·310
63	60½	66½	66½	66	65	66½	69½
276	46	1,434¼	1,186	1,086¾	1,151¼	777	1,970¼
940·76	1,000·10	8,222·45	6,701·32	5,779·07	5,982·68	3,982·46	6,395·90
4,919	7,487	233,424	193,021	176,868	187,366	126,457	320,658
3,751	44,917	170,323	172,811	183,620	188,039	190,510	300,794
2·029	0·720	2·044	2·028	2·015	2·031	2·042	1·381
..	..	1·618	1·595	1·519	1·528	1·497	0·387
4·433	4·457	4·417	4·425	4·414	4·437	4·422	4·432
5·77	16·15	46·27	45·83	45·65	45·78	46·18	31·16
.	..	36·63	36·05	34·41	34·43	33·85	8·73
4·072	0·023	141·079	76·862	52·056	59·570	17·909	79·206
..	..	111·688	60·456	39·251	44·825	13·133	22·198
1·17	2·91	210·04	129·07	90·35	100·67	31·65	149·65
4·18	0·79	67·16	59·55	57·61	59·17	56·58	52·92
..	..	53·17	46·84	43·44	44·52	41·50	14·83
2·157	20·910	45·497	46·350	49·318	50·355	50·904	97·787
..	..	51·184	52·243	56·751	58·099	59·367	184·879

This experiment was made, under the same conditions, for comparison with No. 8 experiment upon the Guibal fan (Table 3).

This reading appears to be incorrect.

APPENDIX B.—TABLES 1 AND 2.—CWMAMAN COLLIERY.—

Type of Ventilator	WADDLE.						
Date 1888	Oct. 28	Oct. 28	Oct. 28	Oct. 29	Oct. 29	Oct. 29	[illegible]
Time	12 50 p.m.	1 8 p.m.	1 30 p.m.	5 3 p.m.	5 30 p.m.	4 0 p.m.	[illegible]
No. of Experiment	*a*	*b*	*c* ‡	1	2	3	4
Condition of Mine	Return Airway to Ventilator closed.		Return Airway to Ventilator closed, with exception of Opening of 3 sq. feet, Air being drawn from Mine.	Mine under ordinary working conditions.			[illegible]
Temperature, atmosphere, wet, degs. Fahr.	57¾	57¾	58	52½	52¾	52½	[illegible]
,, ,, dry, ,,	57¾	57¾	58¼	55	55½	55	[illegible]
,, in fan drift, wet, ,,	89	89	88	87	90	92	[illegible]
,, ,, dry, ,,	89	89	88	87	90	92	[illegible]
,, bottom of pit, ,,	*	*	*	71	72	72½	[illegible]
Pressure of atmosphere, inches of mercury	29·19	29·18	29·17	29·22	29·24	29·22	[illegible]
RESULTS OF OBSERVATIONS:—							
Duration of experiment, minutes	8	8	6	8	8	8	[illegible]
Mean revolutions of engine, per minute	12·625	26·125	25·333	45·375	17·875	26·375	[illegible]
,, ,, fan, per minute	30·474	63·060	61·149	109·525	43·146	63·663	[illegible]
,, ,, anemometer, per minute	*	*	‡	1,616·62	756·62	1,116·75	[illegible]
Water-gauge:—							
Mean depression, at inlet of fan, No. I., inches	*	*	*	5·556	0·933	1·876	[illegible]
,, ,, fan drift, 18† feet from fan, No. II., inches	*	2·000	2·000	5·526	0·922	1·827	[illegible]
,, ,, inside fan, No. IV., inches	*	*	*	*	*	*	[illegible]
,, ,, 16 feet below Guibal drift, No. V., inches	*	*	*	5·305	0·821	1·827	[illegible]
,, ,, bottom of shaft, No. III., inches	*	*	*	4·750	1·150	1·815	[illegible]
Indicator Diagrams:—							
Mean pressure, pounds per square inch:—							
Right-hand engine, back end	(1) 1·20	(18) 1·04	..	(33) 14·00	(36) 3·24	(27) 5·41	[illegible]
,, ,, ,,	(2) 0·77	(19) 1·86	..	(34) 14·13	(37) 2·93	(28) 5·05	[illegible]
,, ,, ,,	(3) 0·93	(20) 2·09	..	(35) 14·06	(38) 3·18	(29) 5·14	[illegible]
,, ,, ,, average	0·96	1·66	..	14·06	3·12	5·20	[illegible]
,, ,, front end	(1) 0·90	(18) 1·15	..	(33) 14·18	(36) 4·01	(27) 5·79	[illegible]
,, ,, ,,	(2) 0·69	(19) 1·82	..	(34) 14·29	(37) 3·71	(28) 5·58	[illegible]
,, ,, ,,	(3) 1·74	(20) 2·19	..	(35) 14·41	(38) 4·14	(29) 5·72	[illegible]
,, ,, ,, average	1·11	1·72	..	14·29	3·95	5·69	[illegible]
,, ,, average	(1) 1·05	(18) 1·10	..	(33) 14·06	(36) 3·62	(27) 5·60	[illegible]
,, ,, ,,	(2) 0·73	(19) 1·84	..	(34) 14·21	(37) 3·32	(28) 5·31	[illegible]
,, ,, ,,	(3) 1·33	(20) 2·14	..	(35) 14·23	(38) 3·66	(29) 5·43	[illegible]
Left-hand engine, back end	(1) 0·75	(18) 1·38	..	(33) 12·72	(36) 2·04	(27) 4·83	[illegible]
,, ,, ,,	(2) 0·75	(19) 1·55	..	(34) 12·76	(37) 2·33	(28) 5·22	[illegible]
,, ,, ,,	(3) 0·59	(20) 1·74	..	(35) 13·73	(38) 2·26	(29) 5·15	[illegible]
,, ,, ,, average	0·70	1·56	..	13·07	2·21	5·07	[illegible]
,, ,, front end	(1) 2·29	(18) 1·66	..	(33) 12·66	(36) 3·06	(27) 5·14	[illegible]
,, ,, ,,	(2) 3·18	(19) 1·12	..	(34) 13·06	(37) 3·28	(28) 4·78	[illegible]
,, ,, ,,	(3) 2·06	(20) 2·06	..	(35) 12·76	(38) 3·09	(29) 4·35	[illegible]
,, ,, ,, average	2·51	1·62	..	12·83	3·14	4·76	[illegible]
,, ,, average	(1) 1·52	(18) 1·52	..	(33) 12·69	(36) 2·55	(27) 4·99	[illegible]
,, ,, ,,	(2) 1·97	(19) 1·33	..	(34) 12·91	(37) 2·80	(28) 5·00	[illegible]
,, ,, ,,	(3) 1·32	(20) 1·91	..	(35) 13·25	(38) 2·68	(29) 4·75	[illegible]
Right and left-hand engines, average	1·32	1·64	..	13·56	3·10	5·18	[illegible]
Steam pressure, pounds per square inch	Nil.	50	52	34	33	42	[illegible]
Vacuum, pounds per square inch	*	13	12	12	12	12	[illegible]
RESULTS OF CALCULATIONS:—							
Weight of cubic foot of air of atmosphere, pound	0·07443	0·07443	0·07425	0·07517	0·07498	0·07517	[illegible]
,, ,, ,, fan drift ,,	0·06944	0·06944	0·06954	0·06983	0·06940	0·07209	[illegible]
,, ,, water, pounds	62·378	62·378	62·373	62·391	62·389	62·391	[illegible]
Temperature of water, degs. Fahr.	57¾	57¾	58¼	55	55½	55	[illegible]
Mean velocity of air, feet per minute	..	..	..	1,562	753	1,098	[illegible]
Velocity of circumference of fan, feet per minute	2,872·1	5943·2	5763·1	10,322·5	4066·4	6,000	[illegible]
Mean volume of air, cubic feet per minute	..	..	..	134,566	64,871	94,592	[illegible]
At normal velocity, volume of air, cubic feet per minute	..	..	..	78,214	95,680	94,592	[illegible]
,, ,, depression at inlet, inches	..	..	..	1·677	2·030	1·876	[illegible]
,, ,, ,, fan drift, inches	..	2·038	2·167	1·867	2·006	1·827	[illegible]
,, ,, theoretical depression, inches	4·297	4·298	4·296	4·331	4·313	4·307	[illegible]
Manometric efficiency, at inlet of fan, per cent.	..	..	..	43·33	47·07	43·55	[illegible]
,, ,, fan drift, per cent.	..	47·41	50·44	43·10	46·51	42·42	[illegible]
Useful effect in air, at inlet of fan, horse-power	..	..	..	117·78	9·53	27·95	[illegible]
,, ,, ,, fan drift, ,,	..	..	..	117·15	9·42	27·22	[illegible]
Motive power of engine, horse-power	6·31	16·23	..	233·04	20·99	51·75	[illegible]
,, utilized, at inlet of fan, per cent.	..	..	..	50·50	45·40	54·00	[illegible]
,, ,, fan drift, per cent.	..	..	..	50·2	44·8	52·6	[illegible]
Equivalent orifice of mine:—							
Inlet water-gauge, square feet	..	..	..	21·55	25·24	26·04	[illegible]
Drift ,, ,,	..	..	..	21·59	25·46	26·37	[illegible]

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* No observation recorded.

† The water-gauge was situated 25 feet from inlet of Guibal fan.

‡ Anemometer failed, owing to excessive velocity of air, when passing through opening of 3 square feet.

APPENDIX B.—TABLE 5.—EXPERIMENTS OF JUNE 8TH, 1889, UPON THE SCHIELE FAN AT NATIONAL COLLIERY.

DIMENSIONS, ETC., OF THE FAN.

Description	centrifugal fan of Schiele type.
Diameter	15 feet 3 inches.
Width, at inlet	6 „ 0 „
„ at periphery	3 „ 0 „
Diameter of inlet	8 „ 10 „

Normal velocity (6,000 feet per minute =) 125·23 revolutions per minute.

DIMENSIONS, ETC., OF THE ENGINE.

Number of cylinders	one.
Diameter of the piston	32 inches.
„ of piston-rod, fore end	4⅝ „
Mean effective area of the piston	795·61 square „
Stroke of piston	36 „
Ratio of transmission	by belting, about 3·15 to one.

SUNDRY PARTICULARS.

Area of place of measurement (Fig. 17, Plate XVI.)...160·97 square feet.

APPENDIX B.—TABLES 1 AND 2.—CWMAMAN COLLIERY.—VIDIMUS OF EXPERIMENTS ON THE GUIBAL AND WADDLE FANS, OCTOBER 27TH, 28TH AND 29TH, 1888.

GUIBAL FAN, 30 FEET IN DIAMETER.

Number of Experiment.	Condition of Mine.	Engine.			Fan.		Air.			Water-gauge, where Air was measured.	Horse-power in the Air.	Percentage of Power utilized.	Temperatures.					Barometer in Air.	Water-gauge at Pit-bottom.
													Bank.		Fan-drift.		Pit-bottom.		
		Revolutions per Minute.	Mean Steam-pressure on Piston.	Horse-power.	Revolutions per Minute.	Speed of Periphery per Minute.	Velocity per Minute.	Volume per Minute.	Volume per Revolution.				Wet.	Dry.	Wet.	Dry.			
			Lbs. per Sq. In.			Feet.	Feet.	Cubic Feet.	Cubic Feet.	Inches.			Degs.	Degs.	Degs.	Degs.	Degs.	Inches.	Inches.
a	Friction of engine	12⅜	2·05	1·4	12·37	1,166	*	*	*	0·07	*	*	61	62	91	91	*	29·28	*
b	Return airway closed	62⅝	10·07	34·3	62·67	5,926	*	*	*	†2·65	*	*	61	62	91	91	*	29·28	*
2	Opening of 3 square feet	63¼	11·32	38·8	63·25	5,961	186	20,880	330	2·60	8·5	22·0	61½	62	91½	91½	*	29·28	*
1	,, 3 ,, ...	64¼	10·57	36·8	64·25	6,055	155	17,372	271	2·60	7·1	19·3	58	62	91	91	*	29·21	*
3	,, 6 ,, ...	64	12·45	43·2	64·00	6,032	316	38,842	607	2·58	15·7	36·6	58¼	62	89½	89½	*	29·20	*
4	,, 6 ,, ...	64⅛	12·45	43·2	64 12	6,043	381	42,771	667	2·55	17·2	39·7	61½	61⅝	93½	93½	*	29·28	*
c	Under ordinary conditions	62½	19·69	66·7	62·50	5,891	797	89,513	1,432	2·45	34·5	51·8	59	60	88	88	72½	29·16	2·00
d	Separation-doors opened	64⅝	25·54	89·4	64·62	6,091	1,206	135,385	2,096	2·09	44·6	49·9	58½	60	86	86	69	29·15	*
e	Air admitted freely	Experiment not completed, owing to heating of crank-pin of engine.																	

WADDLE FAN, 30 FEET IN DIAMETER.

Number of Experiment.	Condition of Mine.	Revolutions per Minute.	Mean Steam-pressure on Piston.	Horse-power.	Revolutions per Minute.	Speed of Periphery per Minute.	Velocity per Minute.	Volume per Minute.	Volume per Revolution.	Water-gauge, where Air was measured.	Horse-power in the Air.	Percentage of Power utilized.	Bank Wet.	Bank Dry.	Fan-drift Wet.	Fan-drift Dry.	Pit-bottom.	Barometer in Air.	Water-gauge at Pit-bottom.
a	Friction of engine	12⅜	1·32	6·3	30·47	2,872	*	*	*	*	*	*	57⅞	57⅞	89	89	*	29·19	*
b	Return airway closed	26¼	1·64	16·2	63·06	5,943	*	*	*	2·00	*	*	57⅞	57⅞	89	89	*	29·18	*
c	Opening of 3 square feet	25⅓	*	*	61·15	5,763	Anemometer failed.			2·00	*	*	58	58⅞	88	88	*	29·17	*
2	Under ordinary conditions	17⅞	3·10	20·9	43·15	4,066	753	64,871	1,503	0·92	9·4	44·8	52⅞	55½	90	90	72	29·24	1·15
3	,, ,, ...	26⅜	5·18	51·7	63·66	6,000	1,098	94,592	1,486	1·83	27·2	52·6	52½	55	92	92	72½	29·22	1·81
1	,, ,, .. .	45⅝	13·56	233·0	109·53	10,323	1,562	134,566	1,227	5·53	117·1	50·2	52¼	55	87	87	71	29·22	4·75
4	Separation-doors opened	26¼	7·18	72·7	64·57	6,085	1,643	141,544	2,192	1·82	40·4	55·6	52	55	86	86	68	29·22	*

* No observation recorded. † Water-guage at fan-inlet.

APPENDIX B.—TABLE 3.—EXPERIMENTS OF JUNE 2ND, 1889, UPON THE GUIBAL FAN AT GREAT WESTERN COLLIERY.

Dimensions, etc., of the Fan.

Description	centrifugal fan of Guibal type.
Diameter	40 feet.
Width, at inlet	12 „
„ at periphery	12 „
Diameter of inlet	14 „

Normal velocity (6,000 feet per minute =) 47·74 revolutions per minute.

Dimensions, etc., of the Engine.

Number of cylinders	one.
Diameter of the piston	36 inches.
„ of piston-rod, fore end	4½ „
Mean effective area of the piston	1009·02 square inches.
Stroke of piston	36 „
Ratio of transmission	direct, as one to one.

Sundry Particulars.

Area of place of measurement (Fig. 8, Plate XV.) ... 102·37 square feet.

APPENDIX B.—TABLE 3.—GREAT WESTERN COLLIERY.—

Type of Ventilator	Guibal.			
Date 1889	June 2	June 2	June 2	J[illegible]
Time	12 37 p.m.	1 0 p.m.	2 49 p.m.	4 [illegible]
No. of Experiment	1	2	3	4
Condition of Mine	Mine under ordinary working conditions.	Return Airway to Ventilator closed.	Return Airway to Ve[illegible] lator closed, wi[illegible] ception of Op[illegible] 3 sq. feet. Air being drawn from Mine.	Air [illegible] dra[illegible] Atm[illegible]
Temperature, atmosphere, wet, degs. Fahr.	60	60	61¼	[illegible]
„ „ dry, „	61¼	62	63¼	[illegible]
„ in fan drift, wet, „	61¼	63	64¼	[illegible]
„ „ dry, „	63	64¼	66¼	[illegible]
Pressure of atmosphere, inches of mercury	29·185	29·19	29·19	[illegible]
Results of Observations:—				
Duration of experiment, minutes	8	8	8	[illegible]
Mean revolutions of engine, per minute	6¾	47¼	47⅞	[illegible]
„ „ fan, per minute	6¾	47¼	47⅞	[illegible]
„ „ anemometer per minute	3¾	219¾	338¾	[illegible]
Water-gauge:—				
Mean depression, at inlet of fan, No. I., inches	0·05	2·58	2·54	[illegible]
„ „ fan drift, 40 feet from fan No. II., inches	0·00	−0·01	0·00	[illegible]
Indicator Diagrams.—				
Mean pressure, pounds per square inch:—				
Back end	(1) 2·124	(4) 9·569	(7) 9·082	(16) [illegible]
„	(2) 2·079	(5) 9·568	(8) 10·639	(17) [illegible]
„	(3) 2·165	(6) 9·809	(9) 9·952	(18) [illegible]
„ average	2·123	9·649	9·891	[illegible]
Front end	(1) 2·256	(4) 11·760	(7) 12·268	(16) [illegible]
„	(2) 2·878	(5) ..	(8) 11·594	(17) [illegible]
„	(3) 2·418	(6) ..	(9) 11·900	(18) [illegible]
„ average	2·517	11·760	11·897	[illegible]
Average	(1) 2·190	(4) 10·664	(7) 10·675	(16) [illegible]
„	(2) 2·478	(5) 9·568	(8) 11·082	(17) [illegible]
„	(3) 2·292	(6) 9·809	(9) 10·926	(18) [illegible]
„ average	2·320	10·013	10·894	[illegible]
Steam pressure, pounds per square inch	51	50	50	54
Results of Calculations:—				
Weight of cubic foot of air of atmosphere, pound	0·07386	0·07381	0·07343	[illegible]
„ „ „ fan drift, „	0·07363	0·07341	0·07315	[illegible]
„ „ water, pounds	62·358	62·355	62·344	[illegible]
Temperature of water, degs. Fahr.	61¼	62	63¾	[illegible]
Mean velocity of air, feet per minute	23¼	225	342	[illegible]
Velocity of circumference of fan, feet per minute	848·23	5,937·62	5,953·33	[illegible]
Mean volume of air, cubic feet per minute	2,406	23,033	36,011	[illegible]
At normal velocity, volume of air, cubic feet per minute	16,572	23,271	35,280	[illegible]
„ „ depression at inlet, inches	2·501	2·633	2·579	[illegible]
„ „ „ fan drift, inches	..	..	1·015	[illegible]
„ „ theoretical depression, „	4·407	4·400	4·381	[illegible]
Manometric efficiency, at inlet of fan, per cent.	56·75	59·84	58·86	[illegible]
„ „ fan drift, „	..	..	*	
Useful effect in air, at inlet of fan, horse-power	0·019	9·356	13·999	[illegible]
„ „ fan drift, „	0·000	..	0·000	
Motive power of engine, horse-power	2·86	88·21	94·68	[illegible]
„ utilized, at inlet of fan, per cent.	0·70	10·60	14·78	[illegible]
„ „ fan drift, „	0·00	..	0·000	..
Equivalent orifice of mine:—				
Inlet water-gauge, square feet	4·085	5·459	8·352	[illegible]
Drift „ „	..	..	..	

APPENDIX B.—TABLE 6.—EXPERIMENTS OF JUNE 9TH 1889, UPON THE WADDLE FAN AT NATIONAL COLLIERY.

Dimensions, etc., of the Fan.

Description	centrifugal fan of Waddle type.
Diameter	45 feet 0 inches.
Width, at inlet	4 „ 2 „
„ at periphery	1 „ 8 „
Diameter of inlet,	15 „ 0 „

Normal velocity (6,000 feet per minute =) 42·44 revolutions per minute.

Dimensions, etc., of the Engine.

Number of cylinders	one.
Diameter of the piston	36 inches.
„ of piston-rod, back end,	5 „
„ „ fore end,	5 „
Mean effective area of the piston	999·20 square inches.
Stroke of piston	42 „
Ratio of transmission	direct, as one to one.

Sundry Particulars.

Area of place of measurement (Fig. 17, Plate XVI.)...160·97 square feet.

APPENDIX B.—TABLE 6.—NATIONAL COLLIERY.-

Type of Ventilator	WADDLE.				
Date 1889	June 9	June 9	June 9	June 9	Jun[illegible]
Time	11 44 a.m.	4 0 p.m.	12 10 p.m.	3 36 p.m.	1 [illegible]
No. of Experiment	*a*	*b*†	1	2	3
Condition of Mine	Return Airway to Ventilator closed.	Mine under ordinary working conditions.	Return Airway to Ventilator closed.	Return Airway: Ventilator closed [illegible] exception of [illegible] of 3 sq. feet	
				Air being drawn from Atmosphere.	Air b[illegible] dra[illegible] fr[illegible] M[illegible]
Temperature, atmosphere, wet, degs. Fahr. ..	56	54	55	55	[illegible]
,, ,, dry, ,, ..	60	56	60	59	[illegible]
,, in fan drift, wet, ,, ..	68¼	68	68¼	69	[illegible]
,, ,, dry, ,, ..	70¼	70	70¾	71	[illegible]
Pressure of atmosphere, inches of mercury ..	29·02	28·98	29·02	28·99	[illegible]
RESULTS OF OBSERVATIONS:—					
Duration of experiment, minutes	8	8	8	8	[illegible]
Mean revolutions of engine, per minute	8½	†0·00	39⅞	45⅜	[illegible]
,, ,, fan, per minute	8½	†0·00	39⅞	45⅜	[illegible]
,, ,, anemometer, per minute ..	*	374⅛	113⅞	150⅝	[illegible]
Water-gauge:—					
Mean depression, at inlet of fan, No. I., inches	0·09	0·00	1·78	2·50	[illegible]
,, ,, fan drift, 50 feet from fan No. II., inches	– 0·08	0·00	– 0·40	– 0·06	– [illegible]
,, ,, bottom of shaft, No. III.	*	0·30	*	*	[illegible]
Indicator Diagrams:—					
Mean pressure, pounds per square inch:—					
Back end	(1) 3·288	..	(4) 6·861	(16) 8·097	[illegible]
,, ...	(2) 3·234	..	(5) 7·449	(17) 8·273	[illegible]
,, ...	(3) 3·089	..	(6) 6·882	(18) 8·561	[illegible]
,, average	3·204	..	7·064	8·310	[illegible]
Front end	(1) 3·590	..	(4) 8·066	(16) 9·046	[illegible]
,, ...	(2) 3·333	..	(5) 8·973	(17) 9·301	[illegible]
,, ...	(3) 3·219	..	(6) 8·120	(18) 9·387	[illegible]
,, average	3·381	..	8·386	9·245	[illegible]
Average	(1) 3·439	..	(4) 7·464	(16) 8·571	(10) [illegible]
,, ...	(2) 3·283	..	(5) 8·211	(17) 8·787	(11) [illegible]
,, ...	(3) 3·154	..	(6) 7·501	(18) 8·975	(12) [illegible]
,, average	3·292	0·00	7·725	8·778	[illegible]
Steam pressure, pounds per square inch	61	*	57	62	[illegible]
RESULTS OF CALCULATIONS:—					
Weight of cubic foot of air of atmosphere, pound	0·07376	0·07421	0·07407	0·07383	0[illegible]
,, ,, ,, fan drift, ,,	0·07237	0·07203	0·07237	0·07188	0[illegible]
,, ,, water, pounds	62·366	..	62·366	62·371	62[illegible]
Temperature of water, degs. Fahr.	60	56	60	59	[illegible]
Mean velocity of air, feet per minute	..	376⅛	121¼	157¼	1[illegible]
Velocity of circumference of fan, feet per minute	1,201·66	0·00	5,566·52	6,379·41	6,41[illegible]
Mean volume of air, cubic feet per minute ..	..	†60,605	19,518	25,312	[illegible]
At normal velocity, volume of air, cubic feet per minute	..	.	21,037	23,805	[illegible]
,, ,, depression at inlet, inches ..	2·243	..	2·067	2·211	[illegible]
,, ,, ,, fan drift, inches	..	..	..	..	[illegible]
,, ,, theoretical depression, inches	4·366	..	4·376	4·353	4[illegible]
Manometric efficiency, at inlet of fan, per cent	51·37	..	47·23	50·79	45[illegible]
,, ,, fan drift, per cent. ..	..	..	..	..	[illegible]
Useful effect in air, at inlet of fan, horse-power	..	..	5·47	9·96	10[illegible]
,, ,, fan drift, ,,	..	..	..	..	[illegible]
Motive power of engine, horse-power	5·930	..	64·470	83·956	[illegible]
,, utilized, at inlet of fan, per cent...	..	..	8·48	11·86	11·7[illegible]
,, ,, fan drift, per cent. ..	..	..	..	..	[illegible]
Equivalent orifice of mine:					
Inlet water-gauge, square feet ..	..	..	5·550	6·062	[illegible]
Drift ,, ,, ..	..	..	..	..	..

* No observation recorded.

† Natural ventilation produced with fan standing.

RESULTS OF EXPERIMENTS ON THE WADDLE FAN.

WADDLE.							
June 9 16 p.m.	June 9 12 43 p.m.	June 9 6 10 p.m.	June 9 5 14 p.m.	June 9 5 44 p.m.	June 9 4 35 p.m.	June 9 4 20 p.m.	June 9 6 35 p.m.
4	5	6	7	8‡	9	10	11
Return Airway to Ventilator closed, with exception of Opening of 6 sq. feet.		Entrance of Air facilitated by opening Separation-doors at Bottom of Pit.	Mine under ordinary working conditions.				Air admitted freely from Atmosphere, by opening Doors on Surface.
Air being rawn from Atmosphere.	Air being drawn from Mine.						
54	55	51	52¼	52	54	54	51
58	60	56	56¼	55	57	56½	56
68¾	68½	62	64¼	65	66	67½	61½
70½	70¾	64	66¼	66¾	67½	69	63
28·99	29·02	28·97	28·98	28·98	28·98	28·98	28·97
8	8	8	8	8	8	8	8
42	43	41⅜	54⅜	40⅜	43	26⅜	39⅝
42	43	41⅞	54⅜	40⅝	43	26⅜	39⅜
182½	219⅝	722⅞	996⅜	782⅛	855¼	570⅝	1,131⅜
1·98	2·11	1·68	3·01	1·63	1·77	0·66	1·49
− 0·05	− 0·14	1·65	3·00	1·62	1·74	0·65	1·47
*	*	*	2·67	1·56	1·70	0·90	*
(13) 7·687	(7) 7·987	(31) 13·679	(25) 23·178	(28) 11·946	(22) 14·027	(19) 6·599	(34) 15·101
(14) 7·756	(8) 8·169	(32) 14·765	(26) 22·929	(29) 12·187	(23) 14·070	(20) 6·735	(35) 15·000
(15) 7·483	(9) 8·169	(33) 14·380	(27) 23·112	(30) ..	(24) 14·434	(21) 6·726	(36) 15·640
7·642	8·108	14·275	23·073	12·066	14·177	6·687	15·247
(13) 8·926	(7) 9·463	(31) 14·356	(25) 22·648	(28) 12·819	(22) 14·670	(19) 7·685	(34) 15·914
(14) 8·724	(8) 9·645	(32) 14·636	(26) 22·894	(29) 12·924	(23) 14·636	(20) 7·752	(35) 15·236
(15) 8·913	(9) 9·626	(33) 15·531	(27) 22·269	(30) ..	(24) 15·099	(21) 8·188	(36) 16·092
8·854	9·578	14·841	22·604	12·871	14·802	7·875	15·747
(13) 8·306	(7) 8·725	(31) 14·017	(25) 22·914	(28) 12·382	(22) 14·349	(19) 7·142	(34) 15·507
(14) 8·240	(8) 8·907	(32) 14·701	(26) 22·912	(29) 12·556	(23) 14·353	(20) 7·244	(35) 15·118
(15) 8·198	(9) 8·897	(33) 14·955	(27) 22·691	(30) ..	(24) 14·767	(21) 7·457	(36) 15·866
8·248	8·843	14·558	22·839	12·469	14·490	7·281	15·497
53	61	61	56	64	61	63	64
0·07396	0·07377	0·07428	0·07427	0·07388	0·07409	0·07433	0·07428
0·07297	0·07209	0·07294	0·07260	0·07203	0·07248	0·07215	0·07303
62·377	62·366	62·387	62·385	62·391	62·382	62·385	62·387
53	60	56	56½	55	57	56½	56
188	225	719⅛	983	778	848	571	1,111⅜
5,937·62	6,078·99	5,902·28	7,740·11	5,707·89	6,078·99	3,728·68	5,637·20
30,262	36,218	115,778	158,234	125,235	136,502	91,914	178,878
30,579	35,746	117,691	122,656	131,640	134,724	147,898	190,385
2·021	2·055	1·735	1·808	1·809	1·724	1·708	1·687
..	..	1·683	1·803	1·791	1·695	1·691	1·665
4·390	4·358	4·398	4·387	4·358	4·378	4·372	4·400
46·03	47·15	39·45	41·21	41·51	39·37	39·06	38·34
..	..	38·26	41·11	41·09	38·71	38·67	37·84
9·43	12·03	30·64	75·02	32·16	38·05	9·55	41·99
..	..	30·09	74·77	31·96	37·41	9·41	41·42
73·424	80·597	128·524	265·035	106·705	132·390	40·579	130·975
12·89	14·92	23·84	28·35	30·14	28·74	23·53	32·06
..	..	23·41	28·21	29·95	28·25	23·18	31·62
8·125	9·443	33·979	34·504	37·152	38·965	42·965	55·795
..	..	34·286	34·816	37·276	39·316	43·282	56·179

This experiment was made, under the same conditions, for comparison with No. 6 experiment upon the Schiele fan (Table 5).

APPENDIX B.—TABLE 6.—NATIONAL COLLIERY.—VIDIMUS OF EXPERIMENTS ON THE WADDLE FAN, 45 FEET IN DIAMETER, JUNE 9TH, 1889.

Number of Experiment.	Condition of Mine.	Engine.			Fan.		Air.			Water-gauge, where Air was measured.	Horse-power in the Air.	Percentage of Power utilized.	Temperatures.					Barometer in Air.	Water-gauge at Pit-bottom.
		Revolutions per Minute.	Mean Steam-pressure on Piston.	Horse-power.	Revolutions per Minute.	Speed of Periphery per Minute.	Velocity per Minute.	Volume per Minute.	Volume per Revolution.				Bank.		Fan-drift.		Pit-bottom.		
													Wet.	Dry.	Wet.	Dry.			
			Lbs. per Sq. In.			Feet.	Feet.	Cubic Feet.	Cubic Feet.	Inches.			Degs.	Degs.	Degs.	Degs.	Degs.	Inches.	Inches.
a	Friction of engine	8½	3·29	5·9	8·50	1,202	*		*	†0·09	*	*	56	60	68½	70¼	*	29·02	*
1	Return airway, closed..	39⅜	7·72	64·4	39·37	5,567	121	19,518	496	†1·78	5·5	8·5	55	60	68½	70¼	*	29·02	*
2	Opening of 3 square feet	45⅛	8·78	83·9	45·12	6,379	157	25,312	559	†2·50	9·3	11·8	55	59	69	71	*	28·99	*
3	,, 3 ,, ...	45⅜	8·91	85·7	45·37	6,415	173	27,928	616	†2·29	10·1	11·7	55	60	68½	70¼	*	29·02	*
4	,, 6 ,, ...	42	8·25	73·4	42·00	5,938	188	30,262	720	†1·98	9·4	12·9	54	58	68¾	70½	*	28·99	*
5	,, 6 ,, ...	43	8·84	80·6	43·00	6,079	225	36,218	842	†2·11	12·0	14·9	55	60	68½	70¼	*	29·02	*
b	Under ordinary conditions	‡0	0·00	0·00	‡0	0	376	60,605	‡	0·00	0·0	‡	54	58	68	70	..	28·98	0·30
10	,, ,, ...	26⅜	7·28	40·6	26·37	3,729	571	91,914	3,484	0·65	9·4	23·2	54	56½	67½	69	*	28·98	0·90
8	,, ,, ...	40⅜	12·47	106·7	40·37	5,708	778	125,235	3,102	1·62	31·9	29·9	52	55	65	66¾	*	28·98	1·56
9	,, ,, ...	43	14·49	132·4	43·00	6,079	848	130,502	3,173	1·74	37·4	28·2	54	57	66	67½	*	28·98	1·70
7	,, ,, ...	54¾	22·84	265·0	54·75	7,740	983	158,234	2,890	3·00	74·8	28·2	52½	56½	61½	66¼	*	28·98	2·67
6	Separation-doors opened	41¾	14·56	128·5	41·75	5,902	719	115,778	2,773	1·65	30·1	23·1	51	56	62	64	*	28·97	*
11	Air admitted freely	39⅞	15·49	130·9	39·87	5,637	1,111	178,878	4,486	1·47	41·4	31·6	51	56	61½	63	*	28·97	*

* No observation recorded. † Water-gauge at fan-inlet. ‡ Natural ventilation, with fan standing.

APPENDIX B.—TABLE 7.—EXPERIMENTS OF JANUARY 19TH AND 20TH, 1889, UPON THE GUIBAL FAN AT PELTON COLLIERY.

DIMENSIONS, ETC., OF THE No. 2 FAN.

Description	centrifugal fan of Guibal type.
Diameter	36 feet.
Width, at inlet	12 „
„ at periphery	12 „
Diameter of inlet	13 „

Normal velocity (6,000 feet per minute =) 53·05 revolutions per minute.

DIMENSIONS, ETC., OF THE ENGINE.

Number of cylinders (1 in reserve)	one.
Diameter of the piston	30 inches.
„ of piston-rod, back end	4⅞ „
„ „ fore end	4⅞ „
Mean effective area of the piston	688·20 square inches.
Stroke of piston	30 inches.
Ratio of transmission	direct, as one to one.

SUNDRY PARTICULARS.

Area of place of measurement (Fig. 19, Plate XVI.)...78·53 square feet.

APPENDIX B.—TABLE 7.—PELTON COLLIERY.—

Type of Ventilator	GUIBAL.			
Date .. 1889	Jan. 19	Jan. 19	Jan. 19	Jan.
Time	7 50 p.m.	7 28 p.m.	6 45 p.m.	[illegible]
No. of Experiment	*a*	*b*	1	[illegible]
Condition of Mine	Return Airway to Ventilator closed.		Return Airway to [illegible] closed, with [illegible] Opening of 3 sq. [illegible]	
			Entrance of Air facilitated by opening Separation-doors at Bottom of Pit.	[illegible]
Temperature, atmosphere, wet, degs. Fahr.	44	44	43½	[illegible]
,, ,, dry, ,,	45½	45½	45	[illegible]
,, in fan drift, wet, ,,	56½	56½	56	[illegible]
,, ,, dry, ,,	56½	56½	56	[illegible]
,, bottom of pit, ,,	*	*	*	[illegible]
Pressure of atmosphere, inches of mercury	29·71	29·71	29·71	[illegible]
RESULTS OF OBSERVATIONS:—				
Duration of experiment, minutes	8	8	8	[illegible]
Mean revolutions of engine, per minute	7·625	54·250	54·125	[illegible]
,, ,, fan, per minute	7·625	54·250	54·125	[illegible]
,, ,, anemometer, per minute	*	*	356·70	[illegible]
Water-gauge:—				
Mean depression, at inlet of fan, No. I., inches	0·050	2·950	2·860	[illegible]
,, ,, fan drift, 16 feet from fan, No. II., inches	0·050	2·900	2·820	[illegible]
,, ,, bottom of shaft, No. III., inches	*	1·000	1·000	[illegible]
Indicator Diagrams:—				
Mean pressure, pounds per square inch:—				
Back end	(34) 1·416	(31) 14·784	(25) 14·754	[illegible]
,,	(35) 0·772	(32) 14·875	(26) 15·249	[illegible]
,,	(36) 4·432	(33) 15·093	(27) 15·404	[illegible]
,, average	2·203	14·917	15·135	[illegible]
Front end	(34) 1·156	(31) 8·838	(25) 9·729	[illegible]
,,	(35) 0·772	(32) 9·643	(26) 8·981	[illegible]
,,	(36) 2·436	(33) 9·182	(27) 9·106	[illegible]
,, average	1·454	9·221	9·272	[illegible]
Average	(34) 1·286	(31) 11·811	(25) 12·241	[illegible]
,,	(35) 0·772	(32) 12·259	(26) 12·115	[illegible]
,,	(36) 3·434	(33) 12·137	(27) 12·255	[illegible]
,, average	1·831	12·069	12·204	[illegible]
Steam pressure, pounds per square inch	61	63	63	[illegible]
RESULTS OF CALCULATIONS:—				
Weight of cubic foot of air of atmosphere, pound	0·07781	0·07781	0·07788	[illegible]
,, ,, ,, fan drift, ,,	0·07613	0·07613	0·07604	[illegible]
,, water, pounds	62·420	62·420	62·421	[illegible]
Temperature of water, degs. Fahr.	45½	45½	45	[illegible]
Mean velocity of air, feet per minute	..	..	359½	[illegible]
Velocity of circumference of fan, feet per minute	862·3	6,135·5	6,120·9	[illegible]
Mean volume of air, cubic feet per minute	..	..	28,232	[illegible]
At normal velocity, volume of air, cubic feet per minute	..	..	27,671	[illegible]
,, ,, depression at inlet, inches	2·420	2·821	2·747	[illegible]
,, ,, ,, fan drift, inches	2·420	2·773	2·709	[illegible]
,, ,, theoretical depression, inches	4·595	4·595	4·595	[illegible]
Manometric efficiency, at inlet of fan, per cent.	52·66	61·39	59·78	[illegible]
,, ,, fan drift, per cent.	52·66	60·34	58·96	[illegible]
Useful effect in air, at inlet of fan, horse-power	..	..	12·72	[illegible]
,, ,, fan drift, ,,	..	..	12·54	[illegible]
Motive power of engine, horse-power	1·45	68·27	68·87	[illegible]
,, utilized, at inlet of fan, per cent.	..	..	18·47	[illegible]
,, ,, fan drift, per cent.	..	..	18·20	[illegible]
Equivalent orifice of mine:				
Inlet water-gauge, square feet	..	..	6·05	[illegible]
Drift ,, ,,	..	..	6·53	[illegible]

* No observation recorded.

Results of Experiments on the Guibal Fan.

Guibal.						
Jan. 19 6 27 p.m.	Jan. 19 7 5 p.m.	Jan. 20 1 30 p.m.	Jan. 20 1 8 p.m.	Jan. 20 12 40 p.m.	Jan. 20 1 57 p.m.	Jan. 20 2 19 p.m.
3	4	5	6	7 ‡	8	9
Return Airway to Ventilator closed, with exception of Opening of 6 sq. feet.		Mine under ordinary working conditions.			Entrance of Air facilitated by opening Separation-doors at Bottom of Pit.	Air admitted freely from Atmosphere, by opening Doors on Surface.
Air being rawn from Mine.	Entrance of Air facilitated by opening Separation-doors at Bottom of Pit.					
42½	43½	44½	43½	42½	44	44½
44	45	46½	46	45½	46¼	47½
56½	56	61	60½	61¼	59¼	45½
56½	56	61	60½	61¼	59¼	45½
*	*	*	*	*	*	*
29·72	29·71	29·62	29·83	29·83	29·82	29·81
8	8	8	8	8	8	8
53·250	53·375	61·250	52·375	32·625	51·375	51·875
53·250	53·375	61 250	52·375	32·625	51·375	51·875
546·00	597·00	2,308·75	2,063·75	1,257·50	2,384·10	3,601·40
2 850	2·729	3 650	2·694	1·050	2·570	1·978
2·800	2·698	3·679	2·631	1·047	2·533	1·833
2·500	1·500	2·812	2·175	0·900	2·067	*
22) 15·155	(28) 15·187	(43) 32·700	(40) 24·265	(37) 11·353	(46) 26·994	(49) 40·241
23) 15·373	(29) 15·472	(44) 32·792	(41) 25·662	(38) 11·859	(47) 29·148	(50) 43·387
24) 15·093	(30) 15·879	(45) 33·108	(42) 25·347	(39) 11·839	(48) 29·145	(51) 43·697
15·207	15·512	32·866	25·091	11·684	28·429	42·442
22) 9·254	(28) 9·749	(43) 21·720	(40) 16·898	(37) 8·101	(46) 17·525	(49) 25·071
23) 9·149	(29) 9·916	(44) 22·320	(41) 17·372	(38) 8·291	(47) 18·024	(50) 25·436
24) 10·104	(30) 9·706	(45) 21·720	(42) 17·938	(39) 7·908	(48) 17·464	(51) 26·667
9·502	9·790	21·920	17·402	8·100	17·671	25·725
22) 12·204	(28) 12·468	(43) 27·210	(40) 20·581	(37) 9·727	(46) 22·260	(49) 32·656
23) 12·261	(29) 12·694	(44) 27·556	(41) 21·517	(38) 10·075	(47) 23·586	(50) 34·412
24) 12·599	(30) 12·792	(45) 27·414	(42) 21·642	(39) 9·873	(48) 23·304	(51) 35·182
12·355	12·651	27·393	21·247	9·892	23·050	34·083
63	63	61	61	60	63	59
0·07808	0·07788	0·07792	0·07801	0·07956	0·07796	0·07778
0·07598	0·07604	0·07551	0·07561	0·07548	0·07578	0·07802
62·422	62·421	62·418	62·419	62·420	62·419	62·416
44	45	46½	46	45½	46¼	47½
546½	597	2,177	1,963	1,230	2,242·5	3,241
6,022·0	6,036·1	6,926·9	5,923·0	3,689·5	5,809·9	5,866·5
42,917	46,832	170,960	154,154	96,592	176,104	254,516
42,755	46,596	148,072	156,140	157,063	181,845	260,280
2·828	2·695	2 738	2·764	2·776	2·740	2·068
2·779	2·665	2·779	2·625	2·768	2·701	1·917
4·599	4·595	4·580	4·587	4·629	4·590	4·652
61·49	58·65	59·78	60·25	59·97	59·69	44·45
60·42	58·00	60·67	57·22	59·80	58·84	41·06
19·27	20·16	98·34	65·45	15·98	71·33	79·34
18·93	19·93	99·12	63·92	15·93	70·30	73·52
68·60	70·41	174·95	116·03	33·65	123·48	184·36
28·09	28·63	56·21	56·40	47·49	57·76	43·03
27·59	28·30	56·65	55·08	47·34	56·93	39·87
9·89	10·95	34·81	36·54	36·86	42·75	70·79
9·98	11·11	34·59	36·93	36·80	43·03	73·56

‡ This experiment was made, under the same conditions, for comparison with No. 5 experiment upon the Waddle fan (Table 8).

APPENDIX B.—TABLE 7.—PELTON COLLIERY.—VIDIMUS OF EXPERIMENTS ON THE GUIBAL FAN, 36 FEET IN DIAMETER, JANUARY 19TH AND 20TH, 1889.

Number of Experiment.	Condition of Mine.	Engine.			Fan.		Air.			Water-gauge, where Air was measured.	Horse-power in the Air.	Percentage of Power utilized.	Temperatures.					Barometer in Air.	Water-gauge at Pit-bottom.
		Revolutions per Minute.	Mean Steam-pressure on Piston.	Horse-power.	Revolutions per Minute.	Speed of Periphery per Minute.	Velocity per Minute.	Volume per Minute.	Volume per Revolution.				Bank.		Fan-drift.		Pit-bottom.		
													Wet.	Dry.	Wet.	Dry.			
			Lbs. per Sq. In.			Feet.	Feet.	Cubic Feet.	Cubic Feet.	Inches.			Degs.	Degs.	Degs.	Degs.	Degs.	Inches.	Inches.
a	Friction of engine	7⅝	1·83	1·4	7·62	862	*	*	*	0·05	*	*	44	45½	56½	56½	*	29·71	*
b	Return airway closed	54¼	12·07	68·3	54·25	6,136		*	*	2·90	*	*	44	45½	56½	56½	*	29·71	1·00
2	Opening of 3 square feet	53¼	11·73	65·1	53·25	6,022	356	27,957	525	2·70	11·9	18·2	42	44	56	56	*	29·72	2·50
1	,, 3 ,, ...	54⅛	12·20	68·8	54·12	6,121	359	28,232	521	2·82	12·5	18·2	43½	45	56	56	*	29·71	1·00
3	,, 6 ,, ...	53¼	12·35	68·6	53·25	6,022	546	42,917	806	2·80	18·9	27·6	42¼	44	56½	56½	*	29·72	2·50
4	,, 6 ,, ...	53⅜	12·65	70·4	53·37	6,036	597	46,882	878	2·70	19·9	28·3	43½	45	56	56	*	29·71	1·50
7	Under ordinary conditions	32⅝	9·89	33·6	32·62	3,690	1,230	96,592	2,961	1·05	15·9	47·3	42½	45½	61¼	61¼	*	29·83	0·90
6	,, ,, ...	52⅜	21·25	116·0	52·37	5,923	1,963	154,154	2,943	2·63	63·9	55·1	43½	46	60½	60½	*	29·83	2·17
5	,, ,, ...	61¼	27·39	174·9	61·25	6,927	2,177	170,960	2,791	3·68	99·1	56·6	44½	46½	61	61	*	29·82	2·81
8	Separation-doors opened	51⅜	23·05	123·5	51·37	5,810	2,242	176,104	3,428	2·53	70·3	56·9	44	46¼	59¼	59¼	*	29·82	2·07
9	Air admitted freely	51⅞	34·08	184·4	51·87	5,867	3,241	254,516	4,906	1·83	73·5	39·9	44½	47½	45½	45½	*	29·81	*

* No observation recorded.

APPENDIX B.—TABLE 8.—EXPERIMENTS OF JANUARY 19TH AND 20TH, 1889, UPON THE WADDLE FAN AT PELTON COLLIERY.

DIMENSIONS, ETC., OF THE FAN.

Description	centrifugal fan of Waddle type.
Diameter	31 feet 7·2 inches.
Width, at inlet	3 „ 3 „
„ at periphery	1 foot 2 „
Diameter of inlet	14 feet 1 „

Normal velocity (6,000 feet per minute =) 60·44 revolutions per minute.

DIMENSIONS, ETC., OF THE ENGINE.

Number of cylinders	one.
Diameter of the piston	24 inches.
„ of piston-rod, back end	$2\frac{15}{16}$ „
„ „ fore end	$3\frac{13}{16}$ „
Mean effective area of the piston	443·30 square inches.
Stroke of piston	24 inches.
Ratio of transmission	direct, as one to one.

SUNDRY PARTICULARS.

Area of place of measurement (Fig. 20, Plate XVI.) ...79·17 square feet

APPENDIX B.—TABLE 8.—PELTON COLLIERY.—

Type of Ventilator	WADDLE.			
Date 1889	Jan. 19	Jan. 19	Jan. 19	[illegible]
Time	12 20 p.m.	12 41 p.m.	3 25 p.m.	[illegible]
No. of Experiment	*a*	*b*	1	[illegible]
Condition of Mine	Return Airway to Ventilator closed.		Return Airway to [illegible] lator closed, [illegible] ception of [illegible] 3 sq. feet.	
			Entrance of Air facilitated by opening Separation-doors at Bottom of Pit.	[illegible]
Temperature, atmosphere, wet, degs. Fahr. ..	44	44½	44¾	[illegible]
,, ,, dry, ,, ..	46	46½	45¼	[illegible]
,, in fan drift, wet, ,, ..	56¼	56½	56¼	[illegible]
,, ,, dry, ,, ..	56½	56¼	56½	[illegible]
,, bottom of pit, ,, ..	*	*	*	[illegible]
Pressure of atmosphere, inches of mercury ..	29·69	29·69	29·69	[illegible]
RESULTS OF OBSERVATIONS :—				
Duration of experiment, minutes	8	8	8	[illegible]
Mean revolutions of engine, per minute	9·00	65·250	65·000	[illegible]
,, ,, fan, per minute	9·00	65·250	65·000	[illegible]
,, ,, anemometer, per minute ..	*	*	283·9	[illegible]
Water-gauge :—				
Mean depression, at inlet of fan, No. I., inches	0·057	2·431	2·400	[illegible]
,, ,, fan drift, 14 feet from fan No. II., inches	0·000	2·112	2·120	[illegible]
,, ,, bottom of shaft, No. III., inches	*	*	*	[illegible]
Indicator Diagrams :—				
Mean pressure, pounds per square inch :—				
Back end	(1) 6·844	(4) 13·571	(7) 13·584	[illegible]
,, ...	(2) 6·896	(5) 13·307	(8) 13·691	[illegible]
,, ...	(3) 6·290	(6) 13·705	(9) 14·365	[illegible]
,, average	6·676	13·528	13·880	[illegible]
Front end	(1) 6·666	(4) 14·076	(7) 13·626	[illegible]
,, ...	(2) 7·339	(5) 14·286	(8) 14·411	[illegible]
,, ...	(3) 6·384	(6) 14·036	(9) 14·631	[illegible]
,, average	6·796	14·132	14·219	[illegible]
Average	(1) 6·755	(4) 13·823	(7) 13·605	[illegible]
,, ...	(2) 7·117	(5) 13·796	(8) 14·051	[illegible]
,, ...	(3) 6·337	(6) 13·870	(9) 14·493	[illegible]
,, average	6·736	13·830	14·050	[illegible]
Steam pressure, pounds per square inch	35	33	35	[illegible]
RESULTS OF CALCULATIONS :—				
Weight of cubic foot of air of atmosphere, pound	0·07767	0·07767	0·07774	[illegible]
,, ,, ,, fan drift, ,,	0·07590	0·07594	·07594	[illegible]
,, ,, water, pounds	62·419	62·418	62·420	[illegible]
Temperature of water, degs. Fahr.	46	46½	45¼	[illegible]
Mean velocity of air, feet per minute	..	..	288	[illegible]
Velocity of circumference of fan, feet per minute	893·4	6,477·3	6,452·5	[illegible]
Mean volume of air, cubic feet per minute ..	..	..	22,801	[illegible]
At normal velocity, volume of air, cubic feet per minute	..	..	21,201	[illegible]
,, ,, depression at inlet, inches ..	2·570	2·085	2·075	[illegible]
,, ,, ,, fan drift, inches	0·000	1·814	1·833	[illegible]
,, ,, theoretical depression, inches	4·584	4·586	4·588	[illegible]
Manometric efficiency, at inlet of fan, per cent.	56·06	45·46	45·22	[illegible]
,, ,, fan drift, per cent. ..	..	39·55	39·95	[illegible]
Useful effect in air, at inlet of fan, horse-power	..	..	8·62	[illegible]
,, ,, fan drift, ,,	..	..	7·61	[illegible]
Motive power of engine, horse-power	3·25	48·49	49·07	[illegible]
,, utilized, at inlet of fan, per cent...	..	..	17·56	[illegible]
,, ,, fan drift, per cent. ..	..	..	15·50	[illegible]
Equivalent orifice of mine :				
Inlet water-gauge, square feet	..	..	5·72	[illegible]
Drift ,, ,, ...	..	..	6·09	[illegible]

---

* No observation recorded.

Results of Experiments on the Waddle Fan.

Waddle.						
Jan. 19 3 52 p.m	Jan. 19 4 47 p.m.	Jan. 20 4 45 p.m.	Jan. 20 5 20 p.m.	Jan. 20 5 45 p.m.	Jan. 20 6 5 p.m.	Jan. 20 6 25 p.m,
3	4	5‡	6	c	7	8
eturn Airway to Ventilator closed, with exception of Opening of 6 sq. feet.		Mine under ordinary working conditions.			Entrance of Air facilitated by opening Separation-doors at bottom of Pit.	Air admitted freely from Atmosphere, by opening Doors on Surface.
Entrance of Air facilitated by opening Separation-oors at Bot-om of Pit.	Air being drawn from Mine.					
45	43½	40	40	39½	39	39
46½	45	42	40	40	39	39
56½	58	59½	59½	59½	57	49
56½	58	59½	59½	59½	57	49
*	*	*	*	*	*	*
29·69	29·69	29·78	29·78	29·79	29·78	29·78
8	8	8	8	8	8	8
66·000	66·250	41·500	57·750	18·687	55·750	45·750
66·000	66·250	41·500	57·750	18·687	55·750	45·750
466·75	598·40	1,095·75	1,588·40	613·70	1,740·00	2,348·50
2·521	2·505	1·000	1·893	0·270	1·780	1·100
2·236	2·241	0·950	1·840	0·150	1·700	1·000
*	2·000	0·800	1·350	0·225	*	*
(10) 15·652	(16) 16·382	(52) 15·817	(55) 27·287	(58) 7·269	(61) 28·317	(64) 29·761
(11) 15·810	(17) 16·414	(53) 16·335	(56) 28·111	(59) 7·254	(62) 28·955	(65) 29·920
(12) 16·198	(18) 17·069	(54) 16·024	(57) 28·158	(60) 7·148	(63) 28·214	(66) 29·621
15·887	16·622	16·058	27·852	7·223	28·495	29·767
(10) 16·996	(16) 17·006	(52) 16·660	(55) 27·634	(58) 7·847	(61) 28·515	(64) 28·469
(11) 16·500	(17) 16·978	(53) 16·890	(56) 27·515	(59) 7·912	(62) 28·110	(65) 27·976
(12) 17·256	(18) 17·410	(54) 17·216	(57) 27·769	(60) 7·765	(63) 28·323	(66) 27·831
16·917	17·131	16·918	27·639	7·842	28·316	28·092
(10) 16·324	(16) 16·694	(52) 16·238	(55) 27·461	(58) 7·558	(61) 28·416	(64) 29·115
(11) 16·155	(17) 16·696	(53) 16·607	(56) 27·813	(59) 7·583	(62) 28·532	(65) 28·948
(12) 16·727	(18) 17·240	(54) 16·620	(57) 27·963	(60) 7·457	(63) 28·269	(66) 28·726
16·402	16·877	16·489	27·746	7·533	28·406	28·930
34	35	35	34	37	35	34
0·07759	0·07784	0·07854	0·07886	0·07890	0·07901	0·07901
0·07586	0·07567	0·07564	0·07564	0·07567	0·07604	0·07736
62·418	62·421	62·425	62·426	62·426	62·426	62·426
46½	45	42	40	40	39	39
468	598·5	1,077·5	1,536	613·5	1,674	2,211½
6,551·8	6,576·6	4,119·7	5,732·8	1,855·05	5,534·3	4,541·6
37,052	47,383	85,306	121,605	48,571	132,531	175,081
33,930	44,887	124,238	127,269	157,094	143,680	231,302
2·114	2·034	2·121	2·073	2·824	2·092	1·919
1·875	1·865	2·015	2·015	1·569	1·998	1·744
4·581	4·583	4·603	4·612	4·614	4·628	4·668
46·14	45·47	46·08	44·95	61·20	45·20	41·11
40·93	40·69	43·78	43·69	34·01	43·17	37·36
14·72	18·70	13·44	36·28	2·06	37·18	30·35
13·05	16·73	12·77	35·27	1·14	35·51	27·59
58·16	60·08	36·77	86·10	7·56	85·09	71·12
25·30	31·12	36·55	42·13	27·24	43·69	42·67
22·43	27·84	34·72	40·96	15·07	41·73	38·79
9·07	11·63	33·25	34·41	36·56	38·81	65·47
9·62	12·31	34·09	34·96	48·88	39·66	68·72

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‡ This experiment was made, under the same conditions, for comparison with No. 7 experiment upon the Guibal fan (Table 7).

APPENDIX B.—TABLE 8.—PELTON COLLIERY.—VIDIMUS OF EXPERIMENTS ON THE WADDLE FAN, 31·6 FEET IN DIAMETER, JANUARY 19TH AND 20TH, 1889.

Number of Experiment.	Condition of Mine.	Engine.			Fan.		Air.			Water-gauge, where Air was measured.	Horse-power in the Air.	Percentage of Power utilized.	Temperatures.					Barometer in Air.	Water-gauge at Pit-bottom.
		Revolutions per Minute.	Mean Steam-pressure on Piston.	Horse-power.	Revolutions per Minute.	Speed of Periphery per Minute.	Velocity per Minute.	Volume per Minute.	Volume per Revolution.				Bank.		Fan-drift.		Pit-bottom.		
													Wet.	Dry.	Wet.	Dry.			
			Lbs. per Sq. In.			Feet.	Feet.	Cubic Feet.	Cubic Feet.	Inches.			Degs.	Degs.	Degs.	Degs.	Degs.	Inches.	Inches.
a	Friction of engine	9	6·73	3·2	9·00	893	*	*	*	0·00	*	*	44	46	56½	56½	*	29·69	*
b	Return airway closed	65¼	13·83	48·4	65·25	6,477	*	*	*	2·11	*	*	44½	46½	56½	56½	*	29·69	*
2	Opening of 3 square feet	64	13·76	47·3	64·00	6,353	309	21,503	382	2·12	8·1	17·3	44	45½	57½	57½	*	29·69	2·00
1	„ 3 „	65	14·05	49·0	65·00	6,453	288	22,801	350	2·12	7·6	15·5	44¾	45½	56½	56½	*	29·69	*
3	„ 6 „	66	16·40	58·2	66·00	6,552	468	37,052	561	2·24	13·1	22·4	45	46½	56½	56½	*	29·69	*
4	„ 6 „	66¼	16·83	60·1	66·25	6,577	598	47,383	715	2·24	16·7	27·8	43½	45	58	58	*	29·69	2·00
c	Under ordinary conditions	18$\frac{11}{16}$	7·53	7·6	18·69	1,855	613	48,571	2,599	0·15	1·1	15·1	39½	40	59½	59½	*	29·79	0·22
5	„ „	41½	16·49	36·8	41·50	4,120	1,077	85,306	2,055	0·95	12·8	34·7	40	42	59½	59½	*	29·78	0·80
6	„ „	57¾	27·75	86·1	57·75	5,733	1,536	121,605	2,105	1·84	35·3	40·9	40	40	59½	59½	*	29·78	1·35
7	Separation-doors opened	55¾	28·41	85·1	55·75	5,534	1,674	132,531	2,377	1·70	35·5	41·7	39	39	57	57	*	29·78	*
8	Air admitted freely	45¾	28·93	71·1	45·75	4,542	2,211	175,084	3,827	1·00	27·6	38·7	39	39	49	49	*	29·78	*

* No observation recorded.

APPENDIX B.—TABLE 9.—EXPERIMENTS OF SEPTEMBER 1st, 1889, UPON THE SCHIELE FAN AT TOWNELEY COLLIERY.

Dimensions, etc., of the Fan.

Description	centrifugal fan of Schiele type.
Diameter	12 feet 0 inches.
Width, at inlet	3 „ 6 „
„ at periphery	2 „ 3 „
Diameter of inlet	7 „ 6 „

Normal velocity (6,000 feet per minute =) 159·15 revolutions per minute.

Dimensions, etc., of the Engine.

Number of cylinders	one.
Diameter of the piston	26 inches.
„ of piston-rod, fore end	4½ „
Mean effective area of the piston	515·026 square inches.
Stroke of piston	48 inches.
Ratio of transmission	by belting, about 4$\frac{4}{9}$ to one.

Sundry Particulars.

Area of place of measurement	64 square feet.

APPENDIX B.—TABLE 9.—TOWNELEY COLLIERY.—

Type of Ventilator	SCHIELE.		
Date 1889	Sept. 1	Sept. 1	Sept. 1
Time	11 0 a.m.	3 25 p.m.	3 47 p.m.
No. of Experiment	a†	b	c
Condition of Mine	Mine under ordinary working conditions.	Return Airway to Ventilator closed.	
Temperature, atmosphere, wet, degs. Fahr. ..	56½	57½	57½
,, ,, dry, ,, ..	58	59½	60
,, in fan drift, wet, ,, ..	63½	63	63
,, ,, dry, ,, ..	64	64	64
Pressure of atmosphere, inches of mercury ..	29·65	29·61	29·61
RESULTS OF OBSERVATIONS:—			
Duration of experiment, minutes	8	8	8
Mean revolutions of engine, per minute	†0	4½	37½
,, ,, fan, per minute	†0	20	65½
,, ,, anemometer, per minute ..	161⅜	*	*
Water-gauge:—			
Mean depression, at inlet of fan, No. I., inches	0·00	0·05	2·34
,, ,, fan drift, 56 feet from fan, No. II., inches	0·03	0·00	0·00
,, ,, bottom of shaft, No. III., ,,	*	*	*
Indicator Diagrams:—			
Mean pressure, pounds per square inch:—			
Back end..	..	(49) 3·465	(52) 7·191
,, ...	..	(50) 3·181	(53) 7·802
,, ...	..	(51) 3·198	(54) 8·377
,, average	..	3·281	7·790
Front end	..	(49) 1·960	(52) 4·650
,, ...	..	(50) 1·150	(53) 5·317
,, ...	..	(51) 1·662	(54) 5·863
,, average	..	1·591	5·277
Average	..	(49) 2·713	(52) 5·920
,, ...	..	(50) 2·166	(53) 6·560
,, ...	..	(51) 2·430	(54) 7·090
,, average	..	2·436	6·524
RESULTS OF CALCULATIONS:—			
Weight of cubic foot of air of atmosphere, pound	0·07704	0·07527	0·07521
,, ,, ,, fan drift, ,,	0·07461	0·07452	0·07452
,, ,, water, pounds	62·377	62·369	62·367
Temperature of water, degs. Fahr...	58	59½	60
Mean velocity of air, feet per minute	167	..	..
Velocity of circumference of fan, feet per minute	..	753·984	6,234·505
Mean volume of air, cubic feet per minute ..	10,688	..	..
At normal velocity, volume of air, cubic feet per minute	..	..	..
,, ,, depression at inlet, inches ..	..	3·160	2·160
,, ,, ,, fan drift, inches	..	0·000	0·000
,, ,, theoretical depression, inches	..	4·477	4·474
Manometric efficiency, at inlet of fan, per cent.	..	70·58	48·27
,, ,, fan drift, per cent. ..	..	..	..
Useful effect in air, at inlet of fan, horse-power	..	..	..
,, ,, fan drift, ,,	0·05	..	..
Motive power of engine, horse-power	..	1·37	30·54
,, utilized, at inlet of fan, per cent. ..	..	..	..
,, ,, fan drift, per cent. ..	..	..	..
Equivalent orifice of mine:—			
Inlet water-gauge, square feet	..	..	..
Drift ,, ,, ...	..	..	..

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* No observation recorded.

† Natural ventilation produced with fan standing.

Results of Experiments on the Schiele Fan.

Schiele.							
Sept. 1	Sept. 1	Sept. 1	Sept. 1	Sept. 1	Sept. 1	Sept. 1	Sept. 1
3 2 p.m.	4 25 p.m.	4 45 p.m.	12 15 p.m.	11 55 a.m.	11 30 a.m.	1 55 p.m.	2 20 p.m.
2	3	4	5	6	7	8	9
Return Airway to Ventilator closed, with exception of Opening of 3 sq. feet, Air being drawn from Atmosphere.	Return Airway to Ventilator closed, with exception of Opening of 6 sq. feet.		Mine under ordinary working conditions.			Entrance of Air facilitated by opening Separation-doors at bottom of Pit.	Air admitted freely from Atmosphere, by opening Doors in Mine and on Surface.
	Air being drawn from Mine.	Air being drawn from Atmosphere.					
58 60 62½ 63¼ 29·61	57½ 60 62¾ 63¼ 29·60	57¼ 59¾ 60¼ 61¾ 29·61	56½ 58 60½ 60¼ 29·65	56¾ 58¼ 61¼ 61½ 29·66	56½ 57½ 61½ 61¼ 29·66	58¾ 59¾ 61 61 29·65	57 58¾ 57¼ 59¼ 29·63
8 38⅜ 170½ 307⅝	8 34⅝ 152⅝ 398⅜	8 37⅜ 165⅝ 506⅝	8 40 176¼ 1,037¾	8 36⅜ 160¼ 946½	8 28¾ 126¼ 764⅞	8 37⅞ 167 1,435½	8 31⅞ 148¼ 2,590
2·49	2·10	2·44	2·60	2·16	1·33	2·18	1·25
0·01 *	0·11 *	0·03 *	2·32 2·23	1·96 1·86	1·21 1·20	1·97 *	1·03 *
(64) 8·433 (65) 8·249 (66) 9·285 8·656 (64) 6·135 (65) 6·180 (66) 6·762 6·359 (64) 7·284 (65) 7·215 (66) 8·023 7·508	(58) 8·059 (59) 8·780 (60) 8·483 8·440 (58) 5·539 (59) 5·476 (60) 6·523 5·846 (58) 6·799 (59) 7·128 (60) 7·504 7·144	(61) 9·201 (62) 9·754 (63) 9·832 9·595 (61) 6·698 (62) 7·381 (63) 7·186 7·088 (61) 7·950 (62) 8·568 (63) 8·510 8·343	(40) 11·421 (41) 12·086 (42) 12·714 12·074 (40) 9·230 (41) 9·397 (42) 10·095 9·574 (40) 10·325 (41) 10·741 (42) 11·405 10·824	(37) 9·949 (38) 10·927 (39) 11·073 10·649 (37) 7·775 (38) 8·296 (39) 8·421 8·084 (37) 8·862 (38) 9·611 (39) 9·747 9·407	(34) 7·959 (35) 7·804 (36) 8·172 7·978 (34) 5·477 (35) 6·216 (36) 6·396 6·029 (34) 6·718 (35) 7·010 (36) 7·284 7·004	(43) 11·451 (44) 12·388 (45) 14·265 12·701 (43) 8·431 (44) 10·048 (45) 10·707 9·728 (43) 9·942 (44) 11·218 (45) 12·486 11·215	(46) 15·169 (47) 16·474 (48) 16·571 16·071 (46) 11·159 (47) 12·666 (48) 12·105 11·977 (46) 13·164 (47) 14·570 (48) 14·338 14·024
0·07520 0·07459 62·367 60 311 6,427·713 19,904	0·07518 0·07459 62·367 60 400½ 5,753·840 25,632	0·07528 0·07488 62·369 59½ 507½ 6,239·217 32,480	0·07561 0·07513 62·377 58 1,022¾ 6,635·059 65,456	0·07560 0·07502 62·376 58¼ 936 6,041·296 59,904	0·07568 0·07501 62·379 57½ 760¼ 4,759·524 48,688	0·07530 0·07507 62·368 59¾ 1,395¾ 6,295·766 89,322	0·07543 0·07531 62·373 58¾ 2,418¼ 5,588·906 154,768
18,579 2·170 0·008 4·476 49·48 0·19 7·80 0·03 36·21 21·54 0·08	26,728 2·283 0·119 4·475 50·95 2·67 8·47 0·44 30·99 27·33 1·42	31,234 2·256 0·027 4·489 50·25 0·62 12·47 0·15 39·29 31·73 0·38	59,190 2·126 1·890 4·504 47·21 41·96 26·80 23·92 54·05 49·57 44·25	59,494 2·130 1·930 4·500 47·33 42·89 20·38 18·49 42·72 47·70 43·28	61,377 2·114 1·920 4·502 46·97 42·65 10·19 9·28 25·14 40·53 36·91	85,125 1·977 1·780 4·493 44·00 39·61 30·63 27·71 53·03 57·76 52·25	166,151 1·440 1·180 4·504 31·97 26·20 30·46 25·10 59·21 51·44 42·56
4·48 ..	6·78 ..	7·99 ..	15·65 16·54	15·71 16·49	16·28 17·05	23·41 24·61	53·37 58·69

APPENDIX B.—TABLE 9.—TOWNELEY COLLIERY.—VIDIMUS OF EXPERIMENTS ON THE SCHIELE FAN, 12 FEET IN DIAMETER, SEPTEMBER 1ST, 1889.

Number of Experiment.	Condition of Mine.	Engine.			Fan.		Air.			Water-gauge, where Air was measured.	Horse-power in the Air.	Percentage of Power utilized.	Temperatures.					Barometer in Air.	Water-gauge at Pit-bottom.
		Revolutions per Minute.	Mean Steam-pressure on Piston.	Horse-power.	Revolutions per Minute.	Speed of Periphery per Minute.	Velocity per Minute.	Volume per Minute.	Volume per Revolution.				Bank.		Fan-drift.		Pit-bottom.		
													Wet.	Dry.	Wet.	Dry.			
			Lbs. per Sq. In.			Feet.	Feet.	Cubic Feet.	Cubic Feet.	Inches.			Degs.	Degs.	Degs.	Degs.	Degs.	Inches.	Inches.
b	Friction of engine	4½	2·43	1·4	20·00	754	*	*	*	†0·06	*	*	57½	59½	63	64	*	29·61	*
c	Return airway closed	37½	6·52	30·5	165·37	6,235	*	*	*	†2·34	*	*	57½	60	63	64	*	29·61	*
1	Opening of 3 square feet	36¾	7·04	30·9	160·37	6,046	265	16,944	105	†2·20	5·8	19·0	57¾	60¼	63½	64½	*	29·61	*
2	" 3 "	38¾	7·51	36·2	170·50	6,428	311	19,904	116	†2·49	7·8	21·5	58	60	62½	63½	*	29·61	*
3	" 6 "	34¾	7·14	31·0	152·62	5,754	400	25,632	167	†2·10	8·5	27·3	57½	60	62¾	63¼	*	29·60	*
4	" 6 "	37¾	8·34	39·3	165·50	6,239	507	32,480	196	†2·44	12·5	31·7	57¼	59½	60¼	61¾	*	29·61	*
a	Under ordinary conditions	‡0	0·00	0·0	‡0·00	0	167	10,688	‡	0·03	0·1	‡	56½	58	63½	64	*	29·65	*
7	" " " .. .	28¾	7·00	25·1	126·25	4,760	761	48,688	385	1·21	9·3	36·9	56½	57¾	61½	61½	*	29·66	1·20
6	" " "	36¾	9·41	42·7	160·25	6,041	936	59,904	374	1·96	18·5	43·3	56¾	58¼	61¼	61½		29·66	1·86
5	" " "	40	10·82	54·1	176·25	6,635	1,023	65,456	371	2·32	23·9	44·3	56½	58	60½	60½	*	29·65	2·23
8	Separation-doors opened	37¼	11·21	53·0	167·00	6,296	1,396	89,322	535	1·97	27·7	52·2	58¾	59¾	61	61	*	29·65	*
	Air admitted freely	33¼	14·02	59·2	148·25	5,589	2,418	154,768	1,037	1·03	25·1	42·6	57	58¾	57½	59½	*	29·63	*

* No observation recorded. † Water-gauge at fan-inlet. ‡ Natural ventilation with fan standing.

APPENDIX B.—TABLE 10.—EXPERIMENTS OF AUGUST 31st, 1889, UPON THE WADDLE FAN AT TOWNELEY COLLIERY.

Dimensions, etc., of the Fan.

Description	centrifugal fan of Waddle type.
Diameter	40 feet 0 inches.
Width, at inlet	4 „ 8 „
„ at periphery	1 „ 6 „
Diameter of inlet and of drift	12 „ 0 „

Normal velocity (6,000 feet per minute =) 47·74 revolutions per minute.

Dimensions, etc., of the Engine.

Number of cylinders	one.
Diameter of the piston	32 inches.
„ of piston-rod, back end	$3\frac{11}{16}$ „
„ „ fore end	$4\frac{1}{2}$ „
Mean effective area of the piston	789·998 square inches.
Stroke of piston	48 inches.
Ratio of transmission	direct, as one to one.

Sundry Particulars.

Area of place of measurement	64 square feet.

APPENDIX B.—TABLE 10.—TOWNELEY COLLIERY.–

Type of Ventilator	**Waddle.**		
Date 1889	August 31	August 31	August 31
Time	11 50 a.m.	5 5 p.m.	5 30 p.m.
No. of Experiment	*a*†	*b*	*c*
Condition of Mine	Mine under ordinary working conditions.	Return Airway to Ventilator closed.	
Temperature, atmosphere, wet, degs. Fahr. ..	60½	62	60½
,, ,, dry, ,, ..	63½	62	61½
,, in fan drift, wet, ,, ..	67	66	66¼
,, ,, dry, ,, ..	67	66	66½
,, bottom of pit, ,, ..	*	*	*
Pressure of atmosphere, inches of mercury ..	29·65	29·63	29·63
Results of Observations:—			
Duration of experiment, minutes	8	8	8
Mean revolutions of engine, per minute	† 0	4½	28
,, ,, fan, per minute	† 0	4½	28
,, ,, anemometer, per minute ..	210¾	*	*
Water-gauge:—			
Mean depression, at inlet of fan, No. I., inches	0·00	0·04	0·81
,, ,, fan drift, 64 feet from fan, No. II., inches	0·00	– 0·23	– 0·21
,, ,, bottom of shaft, No. III., inches	*	*	*
Indicator Diagrams:—			
Mean pressure, pounds per square inch:—			
Back end	..	(16) 2·235	(19) 3·739
,, ...	..	(17) 2·039	(20) 3·352
,, ...	..	(18) 1·620	(21) 3·473
,, average	..	1·965	3·521
Front end	..	(16) 2·486	(19) 3·324
,, ...	..	(17) 2·023	(20) 4·068
,, ...	..	(18) 2·171	(21) 3·880
,, average	..	2·227	3·764
Average	..	(16) 2·361	(19) 3·532
,, ...	..	(17) 2·031	(20) 3·720
,, ...	..	(18) 1·896	(21) 3·676
,, average	..	2·096	3·642
Results of Calculations:—			
Weight of cubic foot of air of atmosphere, pound	0·07476	0·07486	0·07500
,, ,, ,, fan drift, ,,	0·07411	0·07423	0·07414
,, ,, water, pounds	62·346	62·355	62·360
Temperature of water, degs. Fahr.	63¼	62	61¼
Mean velocity of air, feet per minute	215⅞	..	..
Velocity of circumference of fan, feet per minute	..	596·904	3,518·592
Mean volume of air, cubic feet per minute ..	13,816	..	..
At normal velocity, volume of air, cubic feet per minute	..	..	..
,, ,, depression at inlet, inches ..	..	4·040 (?)	2·354
,, ,, ,, fan drift, inches	..	..	..
,, ,, theoretical depression, inches	..	4·507	4·458
Manometric efficiency, at inlet of fan, per cent.	..	90·90 (?)	52·59
,, ,, fan drift, per cent. ..	..	..	..
Useful effect in air, at inlet of fan, horse-power	..	..	..
,, ,, fan drift, ,,	..	..	..
Motive power of engine, horse-power	..	1·97	19·50
,, utilized, at inlet of fan, per cent. ..	..	..	..
,, ,, fan drift, per cent. ..	..	..	..
Equivalent orifice of mine:—			
Inlet water-gauge, square feet	..	..	..
Drift ,, ,, ...	..	..	..

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* No observation recorded.

† Natural ventilation produced with fan standing.

RESULTS OF EXPERIMENTS ON THE WADDLE FAN.

Waddle.							
August 31	August 31	August 31	August 31	August 31	August 31	August 31	August 31
5 30 p.m.	6 10 p.m.	6 30 p.m.	2 20 p.m.	2 40 p.m.	3 0 p.m.	3 50 p.m.	4 10 p.m.
2	3	4	5	6	7	8	9
Return Airway to Ventilator closed, with exception of Opening of 3 sq. feet. Air being drawn from Mine.	Return Airway to Ventilator closed, with exception of Opening of 6 sq. feet.		Mine under ordinary working conditions.			Entrance of Air facilitated by opening Separation-doors at bottom of Pit.	Air admitted freely from Atmosphere, by opening Doors in Mine and on Surface.
	Air being drawn from Mine.	Air being drawn from Atmosphere.					
60½	60½	60½	60½	60½	60½	62¼	61¼
61½	60½	60½	63½	63½	63¾	63	62¼
67	66¾	64¾	63	64	65	63¾	61
67	66¾	64¾	64	64½	65½	63¾	61
-	*	*	*	*	*	*	*
29·63	29·62	29·62	29·63	29·63	29·63	29·63	29·63
8	8	8	8	8	8	8	8
32¾	38½	39¾	40¼	34¾	20¾	39¾	36⅞
32¾	38½	39¾	40¼	34¾	20¾	39¾	36⅞
147¼	324½	340¼	792⅝	671½	428	1,171⅝	2,617⅞
1·05	1·42	1·47	1·49	1·08	0·42	1·40	1·09
- 0·06	0·00	0·02	1·40	0·99	0·39	1·34	1·05
*	*	*	*	*	*	*	*
(22) 3·380	(25) 4·355	(28) 5·073	(1) 5·380	(4) 4·395	(7) 4·347	(10) 5·783	(13) 7·611
(23) 4·011	(26) 5·159	(29) 4·792	(2) 5·720	(5) 5·558	(8) 4·022	(11) 6·406	(14) 8·520
(24) 4·550	(27) 4·565	(30) 4·419	(3) 5·720	(6) 5·706	(9) 3·315	(12) 7·525	(15) 8·316
3·980	4·693	4·762	5·607	5·219	3·895	6·571	8·149
(22) 3·099	(25) 3·974	(28) 4·738	(1) 5·300	(4) 4·893	(7) 4·607	(10) 5·329	(13) 6·121
(23) 4·293	(26) 4·055	(29) 4·333	(2) 5·800	(5) 4·882	(8) 3·077	(11) 5·736	(14) 7·801
(24) 4·420	(27) 5·177	(30) 4·851	(3) 5·580	(6) 5·187	(9) 3·077	(12) 5·752	(15) 7·415
3·904	3·301	4·641	5·560	4·987	3·554	5·605	7·112
(22) 3·239	(25) 4·164	(28) 4·906	(1) 5·340	(4) 4·644	(7) 4·477	(10) 5·556	(13) 6·866
(23) 4·152	(26) 4·607	(29) 4·562	(2) 5·760	(5) 5·220	(8) 3·559	(11) 6·071	(14) 8·160
(24) 4·485	(27) 4·871	(30) 4·636	(3) 5·650	(6) 5·447	(9) 3·196	(12) 6·638	(15) 7·865
3·959	4·548	4·701	5·583	5·104	3·741	6·088	7·630
0·07496	0·07506	0·07506	0·07457	0·07476	0·07473	0·07471	0·07484
0·07407	0·07409	0·07441	0·07476	0·07448	0·07431	0·07458	0·07501
62·358	62·364	62·364	62·346	62·346	62·347	62·348	62·353
61½	60½	60½	63½	63½	63¼	63	62¼
154	327⅞	343⅛	787½	669¾	429¾	1,149½	2,441⅓
4,115·496	4,838·064	4,948·02	5,057·97	4,351·116	2,607·528	4,995·144	4,602·444
9,856	20,984	21,952	50,400	42,864	27,504	73,568	156,256
14,367	26,020	26,615	59,788	59,099	63,279	88,355	203,676
2·231	2·183	2·161	2·096	2·053	2·223	2·020	1·852
..	..	0·020	1·970	1·880	2·060	1·930	1·780
4·454	4·456	4·466	4·463	4·461	4·455	4·462	4·479
50·07	48·99	48·39	46·97	46·02	49·91	45·27	41·35
..	..	0·44	43·92	42·14	46·23	43·26	39·74
1·63	4·69	5·08	11·24	7·45	1·82	16·21	26·82
..	3·30	0·06	11·11	6·83	1·69	15·58	25·83
24·83	33·53	35·45	43·71	33·84	14·86	46·43	53·55
6·24	13·98	14·35	25·64	21·54	12·24	34·91	50·08
..	9·84	0·19	25·41	19·74	11·37	33·53	48·23
3·665	6·752	6·900	15·640	15·666	16·281	24·004	57·440
..	..	..	16·342	16·539	16·858	25·230	58·530

APPENDIX B.—TABLE 10.—TOWNELEY COLLIERY.—VIDIMUS OF EXPERIMENTS ON THE WADDLE FAN, 40 FEET IN DIAMETER, AUGUST 31ST, 1889.

Number of Experiment.	Condition of Mine.	Engine.			Fan.		Air.			Water-gauge, where Air was measured.	Horse-power in the Air.	Percentage of Power utilized.	Temperatures.					Barometer in Air.	Water-gauge at Pit-bottom.
		Revolutions per Minute.	Mean Steam-pressure on Piston.	Horse-power.	Revolutions per Minute.	Speed of Periphery per Minute.	Velocity per Minute.	Volume per Minute.	Volume per Revolution.				Bank.		Fan-drift.		Pit-bottom.		
													Wet.	Dry.	Wet.	Dry.			
			Lbs. per Sq. In.			Feet.	Feet.	Cubic Feet.	Cubic Feet.	Inches.			Degs.	Degs.	Degs.	Degs.	Degs.	Inches.	Inches.
b	Friction of engine	4¾	2·09	1·9	4·75	597	*	*	*	†0·04	*	*	62	62	66	66	*	29·63	*
c	Return airway closed	28	3·64	19·5	28·00	3,519	*	*	*	†0·81	*	*	60¼	61¼	66½	66½	*	29·63	*
2	Opening of 3 square feet	32¾	3·96	24·8	32·75	4,115	154	9,856	301	†1·05	1·6	6·2	60¼	61½	67	67	*	29·63	*
1	„ 3 „	39⅜	4·32*	32·5	39·37	4,948	174	11,160	283	†1·52	2·7	8·2	60½	60½	66½	66½	*	29·62	*
3	„ 6 „	38½	4·55	33·5	38·50	4,838	328	20,984	545	†1·42	4·7	14·0	60½	60½	66¾	66¾	*	29·62	*
4	„ 6 „	39⅜	4·70	35·4	39·37	4,948	343	21,952	557	†1·47	5·1	14·3	60½	60½	64¾	64¾	*	29·62	*
a	Under ordinary conditions	‡0	0·00	0·0	‡0·00	0	216	13,816	‡	0·00	0·0	‡	60½	63½	67	67	*	29·65	*
7	„ „ „	20¾	3·74	14·8	20·75	2,607	430	27,504	1,325	0·39	1·7	11·4	60½	63¼	65	65½	*	29·63	*
6	„ „	34⅝	5·10	33·8	34·62	4,351	670	42,864	1,238	0·99	6·8	19·7	60½	63½	64	64½	*	29·63	*
5	„ „ „	40¼	5·53	43·7	40·25	5,058	787	50,400	1,252	1·40	11·1	25·4	60½	63½	63	64	*	29·63	*
8	Separation-doors opened	39¾	6·09	46·4	39·75	4,995	1,149	73,568	1,851	1·34	15·5	33·5	62¼	63	63¾	63¾	*	29·63	*
9	Air admitted freely	36⅝	7·63	53·6	36·62	4,602	2,441	156,256	4,266	1·05	25·8	48·2	61¼	62¼	61	61	*	29·63	*

* No observation recorded. † Water-gauge at fan-inlet. ‡ Natural ventilation with fan standing.

APPENDIX B.—TABLE 11.—EXPERIMENTS OF FEBRUARY 2ND AND 3RD, 1889, UPON THE GUIBAL FAN AT WINGATE GRANGE COLLIERY.

DIMENSIONS, ETC., OF THE FAN.

Description	centrifugal fan of Guibal type.
Diameter	36 feet.
Width, at inlet	12 „
„ at periphery	12 „
Diameter of inlet	13 „

Normal velocity (6,000 feet per minute =) 53·05 revolutions per minute.

DIMENSIONS, ETC., OF THE ENGINE.

Number of cylinders	one.
Diameter of the piston	30 inches.
„ of piston-rod, back end	3⅝ „
„ „ fore end	4¼ „
Mean effective area of the piston	694·61 square inches.
Stroke of piston	30 inches.
Ratio of transmission	direct, as one to one.

SUNDRY PARTICULARS.

Area of place of measurement (Fig. 28, Plate XVII.)...88·40 square feet.

APPENDIX B.—TABLE 11.—WINGATE GRANGE COLLIERY.—

Type of Ventilator	GUIBAL.			
Date 1889	Feb. 2	Feb. 2	Feb. 2	Feb. 2
Time	3 36 p.m.	3 55 p.m.	4 26 p.m.	5 10 p.m.
No. of Experiment	*a*	*b*	*c*	1
Condition of Mine	Return Airway to Ventilator closed.		Return Airway to Venti[illegible] closed, with excep[illegible] Opening of 3 sq feet	
			Air being drawn from Mine.	Air being drawn from Mine. †
Temperature, atmosphere, wet, degs. Fahr.	30	30½	30	28¼
,, ,, dry, ,,	34½	34½	35	33
,, in fan drift, wet, ,,	91	91	90½	91
,, ,, dry, ,,	91½	91½	91½	91½
bottom of pit, ,,	*	*	*	*
Pressure of atmosphere, inches of mercury	29·53	29·53	29·56	29·46
RESULTS OF OBSERVATIONS:—				
Duration of experiment, minutes	8	8	8	8
Mean revolutions of engine, per minute	6·500	40·375	40·187	40·500
,, ,, fan, per minute	6·500	40·375	40·187	40·500
,, ,, anemometer, per minute	*	*	296·6	280½
Water-gauge:—				
Mean depression, at inlet of fan, No. I., inches	0·100 (?)	1·637	2·062	1·595
,, ,, fan drift, 18 feet from fan, No. II., inches	*	2·000	2·005	1·534
,, ,, bottom of shaft, No. III., inches	*	*	*	*
Indicator Diagrams:—				
Mean pressure, pounds per square inch:—				
Back end	(1) 1·416	(4) 5·156	(7) 6·145	(13) 6·017
,,	(2) 0·989	(5) 6·124	(8) 6·053	(14) 6·371
,,	(3) 1·201	(6) 5·239	(9) 6·110	(15) 5·875
,, average	1·202	5·506	6·102	6·088
Front end	(1) 1·624	(4) 6·725	(7) 7·119	(13) 6·957
,,	(2) 1·519	(5) 6·902	(8) 7·169	(14) 7·327
,,	(3) 1·451	(6) 6·230	(9) 7·028	(15) 7·008
,, average	1·531	6·619	7·105	7·097
Average	(1) 1·520	(4) 5·941	(7) 6·632	(13) 6·487
,,	(2) 1·254	(5) 6·513	(8) 6·611	(14) 6·849
,,	(3) 1·326	(6) 5·734	(9) 6·569	(15) 6·442
,, average	1·366	6·063	6·604	6·593
Steam pressure, pounds per square inch	37	36	36	36
RESULTS OF CALCULATIONS:—				
Weight of cubic foot of air of atmosphere, pound	0·07921	0·07919	0·07921	0·07928
,, ,, ,, fan drift, ,,	0·06987	0·06987	0·06997	0·06970
,, ,, water, pounds	62·422	62·422	62·423	62·420
Temperature of water, degs. Fahr.	34½	34½	35	33
Mean velocity of air, feet per minute	..	..	300½	284½
Velocity of circumference of fan, feet per minute	735·08	4,566·0	4,544·7	4,580·1
Mean volume of air, cubic feet per minute	..	..	26,564	25,150
At normal velocity, volume of air, cubic feet per minute	..	..	35,066	32,943
,, ,, depression at inlet, inches	6·661 (?)	2·826	3·591	2·736
,, ,, ,, fan drift, inches	..	3·453	3·491	2·632
,, ,, theoretical depression, inches	4·451	4·450	4·484	4·448
Manometric efficiency, at inlet of fan, per cent.	..	63·50	80·09	61·51
,, ,, fan drift, per cent.	..	77·60	77·86	59·17
Useful effect in air, at inlet of fan, horse-power	..	..	8·63	6·32
,, ,, fan drift, ,,	..	..	8·39	6·08
Motive power of engine, horse-power	0·934	25·763	27·931	28·101
,, utilized, at inlet of fan, per cent.	..	..	30·89	22·49
,, ,, fan drift, per cent.	..	..	30·03	21·63
Equivalent orifice of mine:				
Inlet water-gauge, square feet	..	..	7·08	7·66
Drift ,, ,,	..	..	7·19	7·76

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* No observation recorded.

† Entrance of air was facilitated by opening separation-doors at Main Coal-seam.

RESULTS OF EXPERIMENTS ON THE GUIBAL FAN.

GUIBAL.							
eb. 2	Feb. 2	Feb. 3	Feb. 3	Feb. 3	Feb. 3	Feb. 3	Feb. 3
47 p.m.	5 30 p.m.	5 39 p.m.	5 10 p.m.	7 10 p.m.	6 10 p.m.	4 55 p.m.	6 50 p.m.
d	3	4	5	6‡	7	8	9
urn Airway to Ventilator closed, with exception of Opening of 6 sq. et.		Mine under ordinary working conditions.			Entrance of Air facilitated by opening Separation-doors at Main Coal-seam.	Mine under ordinary working conditions.	Air admitted freely from Atmosphere, by opening Doors at the Schiele fan on Surface.
ir being wn from Mine.	Air being drawn from Mine. †						
30½ 35 92½ 93	28½ 34½ 91½ 92	35 41 79½ 80½	34 40 80½ 81	36 40½ 79½ 80	34 40 79 79½	34 40 79½ 80½	35 40 79 79½
*	*	*	*	*	*	*	*
29·52	29·45	29·60	29·50	29·74	29·65	29·20	29·66
8	8	8	8	8	8	8	8
39·375	39·625	52·250	42·250	35·375	41·250	25·875	37·875
39·375	39·625	52·250	42·250	35·375	41·250	25·875	37·875
620	710	1,723¼	1,471	1,283⅝	1,600¼	1,073⅜	2,152½
1·992	1·536	2·640	1·710	1·182	1·614	0·610	1·123
1·992	1·519	2·335	1·519	1·069	1·440	0·535	0·990
*	*	*	*	1·100	*	*	*
0) 6·017	(16) 6·251	(61) 20·176	(58) 14·097	(70) 10·354	(64) 15·066	(55) 6·297	(67) 16·784
1) 6·745	(17) 6·124	(62) 19·735	(59) 14·107	(71) 10·133	(65) 15·022	(56) 6·253	(68) 17·577
2) 6·619	(18) 6·569	(63) 20·705	(60) 14·102	(72) 10·177	(66) 15·242	(57) 6·044	(69) 17·022
6·460	6·315	20·205	14·102	10·221	15·110	6·198	17·128
0) 7·510	(16) 7·433	(61) 19·912	(58) 14·923	(70) 11·397	(64) 15·374	(55) 6·652	(67) 17·655
1) 7·735	(17) 7·522	(62) 20·000	(59) 14·767	(71) 10·929	(65) 16·244	(56) 6·889	(68) 17·832
2) 7·646	(18) 7·327	(63) 20·000	(60) 14·330	(72) 10·929	(66) 16·344	(58) 6·785	(69) 17·117
7·564	7·427	19·971	14·673	11·085	16·021	6·775	17·535
0) 6·663	(16) 6·842	(61) 20·044	(58) 14·510	(70) 10·876	(64) 15·220	(55) 6·474	(67) 17·220
1) 7·240	(17) 6·823	(62) 19·868	(59) 14·437	(71) 10·531	(65) 15·683	(56) 6·571	(68) 17·704
2) 7·133	(18) 6·948	(63) 20·352	(60) 14·216	(72) 10·553	(66) 15·793	(57) 6·414	(69) 17·069
7·012	6·871	20·088	14·388	10·653	15·565	6·486	17·331
36	36	35	35	33	35	37	34
07911	0·07901	0·07832	0·07823	0·07875	0·07863	0·07743	0·07864
[illegible]	0·06959	0·07185	0·07150	0·07225	0·07212	0·07088	0·07213
2·423	62·422	62·426	62·426	62·426	62·426	62·426	62·426
35	34½	41	40	40½	40	40	40
[illegible]	707½	1,658½	1,428	1,254½	1,547	1,056½	2,011½
4,452·9	4,481·1	5,908·9	4,778·0	4,000·8	4,664·9	2,926·2	4,283·2
55,648	62,543	146,611	126,235	110,898	136,755	93,395	180,469
74,974	83,732	148,844	158,503	166,307	175,875	191,482	252,775
3·616	2·753	2·721	2·696	2·684	2·669	2·564	2·203
3·616	2·722	2·407	2·394	2·404	2·361	2·249	1·942
4·440	4·436	4·483	4·470	4·508	4·501	4·458	4·500
81·44	62·06	60·70	60·31	58·96	59·30	57·51	48·[illegible]
81·44	61·36	53·70	53·55	53·33	52·45	50·45	43·16
17·47	15·14	61·01	34·02	20·66	34·79	8·98	31·94
17·47	14·97	53·96	30·22	18·68	31·04	7·87	28·16
29·057	28·654	110·463	63·977	39·061	67·572	17·662	69·083
60·12	52·83	55·23	54·73	52·09	51·48	50·83	46·23
60·12	52·24	48·84	47·23	47·09	45·93	44·55	40·76
15·06	19·28	34·68	37·06	39·32	41·47	45·91	65·50
15·06	19·39	36·88	39·36	41·72	43·88	48·76	69·85

‡ This experiment was made, under the same conditions, for comparison with No. e experiment upon the Schiele fan (Table 12).

APPENDIX B.—TABLE 11.—WINGATE GRANGE COLLIERY.—VIDIMUS OF EXPERIMENTS ON THE GUIBAL FAN, 36 FEET IN DIAMETER, FEBRUARY 2ND AND 3RD, 1889.

Number of Experiment.	Condition of Mine.	Engine.			Fan.		Air.			Water-gauge, where Air was measured.	Horse-power in the Air.	Percentage of Power utilized.	Temperatures.					Barometer in Air.	Water-gauge at Pit-bottom.
		Revolutions per Minute.	Mean Steam-pressure on Piston.	Horse-power.	Revolutions per Minute.	Speed of Periphery per Minute.	Velocity per Minute.	Volume per Minute.	Volume per Revolution.				Bank.		Fan-drift.		Pit-bottom.		
													Wet.	Dry.	Wet.	Dry.			
			Lbs. per Sq. In.			Feet.	Feet.	Cubic Feet.	Cubic Feet.	Inches.			Degs.	Degs.	Degs.	Degs.	Degs.	Inches.	Inches.
a	Friction of engine	6½	1·37	0·9	6·50	735	*	*	*	†10·10	*	*	30	34½	91	91½	*	29·53	*
b	Return airway closed	40⅜	6·06	25·7	40·37	4,566	*	*	*	2·00	*	*	30½	34½	91	91½	*	29·53	*
2	Opening of 3 square feet	39⅞	6·67	28·0	39·87	4,510	293	25,945	650	1·49	6·1	21·7	28½	34	91	91½	*	29·45	*
c	,, 3 ,, ...	40$\frac{3}{16}$	6·60	27·9	40·18	4,545	300	26,564	659	2·00	8·4	30·0	30	35	90½	91½	*	29·56	*
1	,, 3 ,, .. .	40½	6·59	28·1	40·50	4,580	284	25,150	621	1·53	6·1	21·6	28½	33	91	91½	*	29·46	*
d	,, 6 ,, ...	39⅜	7·01	29·1	39·37	4,453	629	55,648	1,413	1·99	17·5	60·1	30½	35	92½	93	*	29·52	*
3	,, 6 ,, ...	39⅝	6·87	28·6	39·62	4,481	707	62,543	1,578	1·52	14·9	52·2	28½	34½	91½	92	*	29·45	*
8	Under ordinary conditions	25⅞	6·48	17·6	25·87	2,926	1,056	93,395	3,609	0·53	7·8	44·5	34	40	79½	80½	*	29·20	*
6	,, ,, .. .	35⅜	10·65	39·6	35·37	4,001	1,254	110,898	3,135	1·07	18·7	47·1	36	40½	79½	80	*	29·74	1·10
5	,, ,, ...	42¼	14·39	64·0	42·25	4,778	1,428	126,235	2,988	1·52	30·2	47·2	34	40	80½	81	*	29·50	*
4	,, ,, ...	52¼	20·09	110·5	52·25	5,909	1,658	146,611	2,806	2·34	54·0	48·8	35	41	79½	80½	*	29·60	*
7	Separation-doors opened	41¼	15·56	67·6	41·25	4,665	1,547	136,755	3,315	1·44	31·0	45·9	34	40	79	79½	*	29·65	*
9	Air admitted freely	37⅞	17·33	69·1	37·87	4,283	2,041	180,469	4,765	0·99	28·2	40·7	35	40	79	79½	*	29·60	*

* No observation recorded. † Water-gauge at fan-inlet.

APPENDIX B.—TABLE 12.—EXPERIMENTS OF FEBRUARY 2ND AND 3RD, 1889, UPON THE SCHIELE FAN AT WINGATE GRANGE COLLIERY.

Dimensions, etc., of the Fan.

Description	centrifugal fan of Schiele type.
Diameter	12 feet 0 inches.
Width, at inlet	3 „ 4 „
„ at periphery	2 „ 0 „
Diameter of inlet	7 „ 3 „

Normal velocity (6,000 feet per minute =) 159·15 revolutions per minute.

Dimensions, etc., of the Engine.

Number of cylinders	one.
Diameter of the piston	25 inches.
„ of piston-rod, fore end	3¼ „
Mean effective area of the piston	486·73 square inches.
Stroke of piston	24 inches.
Ratio of transmission	by rope gearing, about 2·6 to one.

Sundry Particulars.

Area of place of measurement (Fig. 29, Plate XVII.) 78·47 square feet.

APPENDIX B.—TABLE 12.—WINGATE GRANGE COLLIERY.

Type of Ventilator	SCHIELE.		
Date 1889	Feb. 3	Feb. 2	Feb. 2
Time	9 19 a.m.	9 20 p.m.	9 45 p.m.
No. of Experiment	a‡	b	c
Condition of Mine	Mine under ordinary working conditions.	Return Airway to Ventilator closed.	
Temperature, atmosphere, wet, degs. Fahr. ..	35½	30¼	30
" " dry, " ..	39¾	34½	34½
" in fan drift, wet, " ..	87	75½	82
" " dry, " ..	87½	76	83
" bottom of pit, " ..	*	*	*
Pressure of atmosphere, inches of mercury ..	29·27	29·43	29·43
RESULTS OF OBSERVATIONS:—			
Duration of experiment, minutes	8	8	8
Mean revolutions of engine, per minute	‡ 0·000	9·500	71·250
" " fan, per minute	‡ 0·000	21·875	166·000
" " anemometer, per minute ..	880	−26¾†	−2¼†
Water-gauge:—			
Mean depression, at inlet of fan, No. I., inches	0·000	0·060	2·350
" " fan drift, 55 feet from fan No. II., inches	0·000	0·012	2·187
" " bottom of shaft, No. III., inches	*	*	*
Indicator Diagrams:—			
Mean pressure, pounds per square inch:—			
Back end	..	(22) 5·453	(25) 10·362
"	..	(23) 5·373	(26) 11·661
"	..	(24) 5·692	(27) 11·843
" average	..	5·506	11·288
Front end	..	(22) 4·059	(25) 10·470
"	..	(23) 3·670	(26) 9·742
"	..	(24) 4·020	(27) 9·857
" average	..	3·916	10·023
Average	..	(22) 4·756	(25) 10·416
"	..	(23) 4·522	(26) 10·702
"	..	(24) 4·856	(27) 10·840
" average	..	4·711	10·653
Steam pressure, pounds per square inch	..	36	35
RESULTS OF CALCULATIONS:			
Weight of cubic foot of air of atmosphere, pound	0·07760	0·07892	0·07892
" " " fan drift, "	0·06991	0·07213	0·07104
" " water, pounds	62·426	62·422	62·422
Temperature of water, degs. Fahr.	39¾	34½	34½
Mean velocity of air, feet per minute	872	−39⅝†	−13¼†
Velocity of circumference of fan, feet per minute	0·00	824·4	6,256·5
Mean volume of air, cubic feet per minute ..	68,426	†	†
At normal velocity, volume of air, cubic feet per minute	..	..	..
" " depression at inlet, inches ..	..	2·648	2·161
" " " fan drift, inches	..	0·662	2·011
" " theoretical depression, inches	..	4·509	4·477
Manometric efficiency, at inlet of fan, per cent.	..	58·73	48·27
" " fan drift, per cent. ..	..	14·68	44·92
Useful effect in air, at inlet of fan, horse-power	..	..	..
" " fan drift, "	..	..	..
Motive power of engine, horse-power . ..	..	2·640	44·763
" utilized, at inlet of fan, per cent. ..	..	..	..
" " fan drift, per cent ..	..	..	..
Equivalent orifice of mine:	..		
Inlet water-gauge, square feet	..	..	..
Drift " "	..	..	..

* No observation recorded.

† The air was apparently reversed in this experiment, as the anemometer gave a negative re

owing to the production of air-eddies.

‡ Natural ventilation produced with fan standing.

Results of Experiments on the Schiele Fan.

Schiele.							
b. .	Feb. 2 11 8 p.m.	Feb. 2 10 30 p.m.	Feb. 3 12 31 p.m.	Feb. 3 12 6 p.m.	Feb. 3 11 20 a.m.	Feb. 3 10 47 a.m.	Feb. 3 1 52 p.m.
	3	4	5	d	e §	6	7
Return airway to entilator sed, with eption of pening 3 sq. feet. ir being wn from Mine.	Return Airway to Ventilator closed, with exception of Opening of 6 sq. feet.		Entrance of Air facilitated by opening Separation-doors at Main Coal-seam.	Mine under ordinary working conditions.			Air admitted freely from Atmosphere, by opening Doors on Surface.
	Air being drawn from Mine.	Air being drawn from Mine.					
29½	31	29½	37	38	38	37	37
34	35	34	40	41¾	41½	40	40
93	91½	91	76	79	81	85½	72½
93½	92	91½	76½	79½	81½	86	73½
*	*	*	*	*	*	*	*
29·41	29·39	29·40	29·20	29·20	29·20	29·20	29·20
8	8	8	8	8	8	8	8
69·250	66·750	69·250	61·000	78·000	69·500	38·625	58·500
160·250	152·000	161·500	141·250	178·625	159·250	88·375	134·125
330	441⅞	491⅝	1,456⅝	1,723⅛	1,507⅛	1,040⅝	1,673
2·120	1·936	2·175	1·415	1·921	1·387	0·534	1·245
2·014	1·702	1·852	0·669	1·504	1·097	0·196	0·261
	*	*	*	*	*	*	*
28) 10·336	(37) 10·521	(31) 10·706	(49) 16·418	(46) 23·142	(43) 17·630	(40) 7·800	(52) 17·121
29) 10·402	(38) 10·362	(32) 11·417	(50) 16·716	(47) 22·836	(44) 18·722	(41) 7·562	(53) 16·766
30) 10·336	(39) 10·905	(33) 11·338	(51) 16·915	(48) 22·537	(45) 18·719	(42) 7·880	(54) 16·865
10·358	10·596	11·154	16·683	22·838	18·357	7·747	16·917
28) 10·005	(37) 9·290	(31) 9·584	(49) 15·025	(46) 20·843	(43) 16·953	(40) 6·975	(52) 15·522
29) 9·465	(38) 9·267	(32) 9·782	(50) 14·776	(47) 20·597	(44) 16·855	(41) 7·005	(53) 16·070
30) 8·849	(39) 9·114	(33) 10·233	(51) 15·075	(48) 20·099	(45) 17·374	(42) 7·062	(54) 16·418
9·439	9·224	9·866	14·958	20·513	17·061	7·014	16·003
28) 10·171	(37) 9·905	(31) 10·145	(49) 15·721	(46) 21·992	(43) 17·292	(40) 7·387	(52) 16·321
29) 9·934	(38) 9·815	(32) 10·600	(50) 15·746	(47) 21·717	(44) 17·788	(41) 7·284	(53) 16·418
30) 9·592	(39) 10·010	(33) 10·785	(51) 15·995	(48) 21·318	(45) 18·047	(42) 7·471	(54) 16·642
9·899	9·910	10·510	15·821	21·676	17·709	7·381	16·460
31	34	33	35	34	34	34	35
0·07897	0·07873	0·07894	0·07738	0·07709	0·07713	0·07736	0·07738
0·06925	0·06946	0·06955	0·07148	0·07100	0·07068	0·06997	0·07199
62·422	62·423	62·422	62·426	62·425	62·425	62·426	62·426
34	35	34	40	41¾	41½	40	40
333	443½	492½	1,415	1,658½	1,462	1,025	1,613
6,039·8	5,728·8	6,088·42	5,323·7	6,732·3	6,002·1	3,330·8	5,055·1
26,131	34,801	38,646	111,035	130,142	114,723	80,432	126,572
25,951	36,438	38,083	125,106	115,953	114,651	144,845	150,113
2·091	2·122	2·112	1·796	1·525	1·385	1·731	1·753
1·986	1·866	1·798	0·849	1·193	1·096	0·635	0·367
4·428	4·424	4·433	4·444	4·420	4·382	4·398	4·459
47·23	47·97	47·65	40·41	34·51	31·60	39·36	39·31
44·65	42·18	40·56	19·11	26·99	25·01	14·44	8·23
8·73	10·61	13·24	24·76	39·40	25·08	6·77	24·84
8·29	9·33	11·28	11·70	30·85	19·74	2·48	5·20
40·445	39·028	42·941	56·940	99·754	72·094	16·820	56·812
21·58	27·18	30·83	43·48	35·19	34·78	40·24	43·72
20·49	23·90	26·26	20·54	27·55	27·38	14·74	9·15
6·85	9·55	10·01	35·73	35·83	37·14	42·16	43·51
7·03	10·19	10·85	52·08	40·46	41·77	69·52	95·31

§ This experiment was made, under the same conditions, for comparison with No. 6. experiment upon the Guibal fan (Table 11).

Entrance of air was facilitated by opening separation-doors at Main Coal-seam.

APPENDIX B.—TABLE 12.—WINGATE GRANGE COLLIERY.-

Type of Ventilator	SCHIELE.		
Date 1889	Feb. 3	Feb. 2	Feb. 2
Time	9 19 a.m.	9 20 p.m.	9 45 p.m.
No. of Experiment	*a*‡	*b*	*c*
Condition of Mine	Mine under ordinary working conditions.	Return Airway to Ventilator closed.	
Temperature, atmosphere, wet, degs. Fahr. ..	35½	30¼	30
,, ,, dry, ,, ..	39¾	34½	34½
,, in fan drift, wet, ,, ..	87	75½	82
,, ,, dry, ,, ..	87½	76	83
,, bottom of pit, ,, ..	*	*	*
Pressure of atmosphere, inches of mercury ..	29·27	29·43	29·43
RESULTS OF OBSERVATIONS:—			
Duration of experiment, minutes	8	8	8
Mean revolutions of engine, per minute	‡ 0·000	9 500	71·250
,, ,, fan, per minute	‡ 0·000	21·875	166·000
,, ,, anemometer, per minute ..	880	− 26¾†	− 2¾†
Water-gauge:—			
Mean depression, at inlet of fan, No. I., inches	0·000	0·050	2·350
,, ,, fan drift, 55 feet from fan No. II., inches	0·000	0·012	2·187
,, ,, bottom of shaft, No. III., inches	*	*	*
Indicator Diagrams:—			
Mean pressure, pounds per square inch:—			
Back end	..	(22) 5·453	(25) 10·362
,, ...	..	(23) 5·373	(26) 11·661
,, ...	..	(24) 5·692	(27) 11·843
,, average	..	5·506	11·288
Front end	..	(22) 4·059	(25) 10·470
,, ...	..	(23) 3·670	(26) 9·742
,, ...	..	(24) 4·020	(27) 9·837
,, average	..	3·916	10·016
Average	..	(22) 4·756	(25) 10·416
,, ...	..	(23) 4·522	(26) 10·702
,, ...	..	(24) 4·856	(27) 10·840
,, average	..	4·711	10·653
Steam pressure, pounds per square inch	..	36	35
RESULTS OF CALCULATIONS:—			
Weight of cubic foot of air of atmosphere, pound	0·07760	0·07892	0·07892
,, ,, ,, fan drift, ,,	0·06991	0·07213	0·07104
,, ,, water, pounds	62·426	62·422	62·422
Temperature of water, degs. Fahr.	39¾	34½	34½
Mean velocity of air, feet per minute	872	− 39¾†	− 13¾†
Velocity of circumference of fan, feet per minute	0·00	824·4	6,256·5
Mean volume of air, cubic feet per minute ..	68,426	†	†
At normal velocity, volume of air, cubic feet per minute	..	..	..
,, ,, depression at inlet, inches ..	..	2·648	2·161
,, ,, ,, fan drift, inches	..	0·662	2·011
,, ,, theoretical depression, inches	..	4·509	4·477
Manometric efficiency, at inlet of fan, per cent.	..	58·73	48·27
,, ,, fan drift, per cent. ..	..	14·68	44·92
Useful effect in air, at inlet of fan, horse-power	..	..	..
,, ,, fan drift, ,,	..	..	..
Motive power of engine, horse-power	..	2·640	44·783
,, utilized, at inlet of fan, per cent. ..	..	..	..
,, ,, fan drift, per cent. ..	..	..	..
Equivalent orifice of mine:	..		
Inlet water-gauge, square feet	..	..	..
Drift ,, ,, ...	..	..	..

---

* No observation recorded.

† The air was apparently reversed in this experiment, as the anemometer gave a negative re-
owing to the production of air-eddies.

‡ Natural ventilation produced with fan standing.

Results of Experiments on the Schiele Fan.

Schiele.							
b.	Feb. 2	Feb. 2	Feb. 3	Feb. 3	Feb. 3	Feb. 3	Feb. 3
.	11 8 p.m.	10 30 p.m.	12 31 p.m.	12 6 p.m.	11·20 a.m.	10·47 a.m.	1 52 p.m.
	3	4	5	d	e§	6	7
Return Airway to Ventilator closed, with exception of Opening of 3 sq. feet. Air being drawn from Mine.	Return Airway to Ventilator closed, with exception of Opening of 6 sq. feet.		Entrance of Air facilitated by opening Separation-doors at Main Coal-seam.	Mine under ordinary working conditions.			Air admitted freely from Atmosphere, by opening Doors on Surface.
	Air being drawn from Mine.	Air being drawn from Mine.					
29⅜	31	29½	37	38	38	37	37
34	35	34	40	41¾	41½	40	40
93	91½	91	76	79	81	85½	72½
93½	92	91½	76½	79½	81½	86	73½
*	*	*	*	*	*	*	*
29·41	29·39	29·40	29·20	29·20	29·20	29·20	29·20
8	8	8	8	8	8	8	8
69·250	66·750	69·250	61·000	78·000	69·[illegible]00	38·625	58·500
160·250	152·000	161·500	141·250	178·625	159·250	88·375	134·125
330	441⅞	491⅞	1,456⅞	1,723⅛	1,507⅛	1,040⅞	1,673
2·120	1·936	2·175	1·415	1·921	1·387	0·534	1·245
2·014	1·702	1·852	0·669	1·504	1·097	0·196	0·261
*	*	*	*	*	*	*	*
(28) 10·336	(37) 10·521	(31) 10·706	(49) 16·418	(46) 23·142	(43) 17·630	(40) 7·800	(52) 17·121
(29) 10·402	(38) 10·362	(32) 11·417	(50) 16·716	(47) 22·836	(44) 18·722	(41) 7·562	(53) 16·766
(30) 10·336	(39) 10·905	(33) 11·338	(51) 16·915	(48) 22·537	(45) 18·719	(42) 7·880	(54) 16·865
10·358	10·596	11·154	16·683	22·838	18·357	7·747	16·917
(28) 10·005	(37) 9·290	(31) 9·584	(49) 15·025	(46) 20·843	(43) 16·953	(40) 6·975	(52) 15·522
(29) 9·465	(38) 9·267	(32) 9·782	(50) 14·776	(47) 20·597	(44) 16·855	(41) 7·005	(53) 16·070
(30) 8·849	(39) 9·114	(33) 10·233	(51) 15·075	(48) 20·099	(45) 17·374	(42) 7·062	(54) 16·418
9·439	9·224	9·866	14·958	20·513	17·061	7·014	16·003
(28) 10·171	(37) 9·905	(31) 10·145	(49) 15·721	(46) 21·992	(43) 17·292	(40) 7·387	(52) 16·321
(29) 9·934	(38) 9·815	(32) 10·600	(50) 15·746	(47) 21·717	(44) 17·788	(41) 7·284	(53) 16·418
(30) 9·592	(39) 10·010	(33) 10·785	(51) 15·995	(48) 21·318	(45) 18·047	(42) 7·471	(54) 16·642
9·899	9·910	10·510	15·821	21·676	17·709	7·381	16·460
31	**34**	**33**	**35**	**34**	**34**	**34**	**35**
0·07897	0·07873	0·07894	0·07738	0·07709	0·07713	0·07736	0·07738
0·06925	0·06946	0·06955	0·07148	0·07100	0·07068	0·06997	0·07199
62·422	62·423	62·422	62·426	62·425	62·425	62·426	62·426
34	35	34	40	41¾	41½	40	40
333	443¼	492½	1,415	1,658¼	1,462	1,025	1,613
6,039·8	5,728·8	6,088·42	5,323·7	6,732·3	6,002·1	3,330·8	5,055·1
26,131	34,801	38,646	111,035	130,142	114,723	80,432	126,572
25,951	36,438	38,083	125,106	115,953	114,651	144,845	150,113
2·091	2·122	2·112	1·796	1·525	1·385	1·731	1·753
1·986	1·866	1·798	0·849	1·193	1·096	0·635	0·367
4·428	4·424	4·433	4·444	4·420	4·382	4·398	4·459
47·23	47·97	47·65	40·41	34·51	31·60	39·36	39·31
44·85	42·18	40·56	19·11	26·99	25·01	14·44	8·23
8·73	10·61	13·24	24·76	39·40	25·08	6·77	24·84
8·29	9·33	11·28	11·70	30·85	19·74	2·48	5·20
40·445	39·028	42·941	56·940	90·754	72·094	16·820	56·812
21·58	27·18	30·83	43·48	35·19	34·78	40·24	43·72
20·49	23·90	26·26	20·54	27·55	27·38	14·74	9·15
6·85	9·55	10·01	35·73	35·83	37·14	42·16	43·51
7·03	10·19	10·85	52·08	40·46	41·77	69·52	95·31

§ This experiment was made, under the same conditions, for comparison with No. 6. experiment upon the Guibal fan (Table 11).

Entrance of air was facilitated by opening separation-doors at Main Coal-seam.

APPENDIX B.—TABLE 12.—WINGATE GRANGE COLLIERY.—VIDIMUS OF EXPERIMENTS ON THE SCHIELE FAN, 12 FEET IN DIAMETER, FEBRUARY 2ND AND 3RD, 1889.

Number of Experiment.	Condition of Mine.	Engine.			Fan.		Air.			Water-gauge, where Air was measured.	Horse-power in the Air.	Percentage of Power utilized.	Temperatures.					Barometer in Air.	Water-gauge at Pit-bottom.
													Bank.		Fan-drift.				
		Revolutions per Minute.	Mean Steam-pressure on Piston.	Horse-power.	Revolutions per Minute.	Speed of Periphery per Minute.	Velocity per Minute.	Volume per Minute.	Volume per Revolution.				Wet.	Dry.	Wet.	Dry.	Pit-bottom.		
			Lbs. per Sq. In.			Feet.	Feet.	Cubic Feet.	Cubic Feet.	Inches.			Degs.	Degs.	Degs.	Degs.	Degs.	Inches.	Inches.
b	Friction of engine	9½	4·71	2·6	21·87	824	†−40	†	†	0·01	†	†	30½	34½	75½	76	*	29·43	*
c	Return airway, closed	71¼	10·65	44·7	166·00	6,257	†−13	†	†	2·19	†	†	30	34½	82	83	*	29·43	*
2	Opening of 3 square feet	69¼	9·90	40·4	160·25	6,040	333	26,131	163	2·01	8·3	20·5	29½	34	93	93½	*	29·41	*
1	" 3 "	70	9·35	38·6	160·62	6,054	264	20,716	129	2·00	6·5	16·9	29½	34	92	92½	*	29·38	*
3	" 6 "	66¾	9·91	39·0	152·00	5,729	443	34,801	228	1·70	9·3	23·9	31	35	91½	92	*	29·39	*
4	" 6 "	69¼	10·51	42·9	161·50	6,088	492	38,646	239	1·85	11·3	26·3	29½	34	91	91½	*	29·40	*
a	Under ordinary conditions	‡0	0·00	0·0	‡0·00	0	872	68,426	‡	0·00	0·0	‡	35½	39¾	87	87½	*	29·27	*
6	" "	38⅝	7·38	16·8	88·37	3,331	1,025	80,432	910	0·20	2·5	14·7	37	40	85½	86	*	29·20	*
e	" "	69	17·71	72·1	159·25	6,002	1,462	114,723	720	1·10	19·7	27·4	38	41½	81	81½	*	29·20	*
d	" "	78	21·67	99·8	178·62	6,732	1,658	130,142	728	1·50	30·8	27·6	38	41¾	79	79½	*	29·20	*
5	Separation-doors opened	61	15·82	56·9	141·25	5,324	1,415	111,035	786	0·67	11·7	20·5	37	40	76	76½	*	29·20	*
7	Air admitted freely	58½	16·46	56·8	134·12	5,055	1,613	126,572	944	0·26	5·2	9·1	37	40	72½	73½	*	29·20	*

* No observation recorded.

† The air was apparently reversed in this experiment as the anemometer gave a negative reading owing to the production of air-eddies.

‡ Natural ventilation with fan standing.

APPENDIX C.—TABLE 13.—SUMMARY OF EXPERIMENTS, CWMAMAN COLLIERY—GUIBAL FAN.

No. of Experiment.	Observations.				Calculations.								
	Mean Revolutions of Fan per Minute.	Mean Volume of Air per Minute.	Depression at		Equivalent Orifice.		Volume of Air per Minute at Normal Velocity.	Depression at Inlet at Normal Velocity.	Theoretical Depression at Normal Velocity.	Manometric Efficiency at Inlet of Fan.	Useful Effect in Air at Inlet of Fan.	Motive Power of Engine.	Motive Power utilized at Inlet of Fan.
			Inlet.	Drift.	Inlet Depression.	Drift Depression.							
		Cubic Feet.	Inches.	Inches.	Sq. Feet.	Sq. Feet.	Cubic Feet.	Inches.	Inches.	Per Cent.	Horsepower.	Horsepower.	Per Cent.
1	64·250	17,372	2·600	2·600	4·04	4·04	17,212	2·552	4·276	59·68	7·11	36·79	19·32
2	63·250	20,880	2·600	2·600	4·86	4·86	21,015	2·633	4·283	61·47	8·54	38·77	22·02
3	64·000	38.842	2·600	2·583	9·03	9·07	38,635	2·572	4·281	60·08	15·90	43·16	36·83
4	64·125	42,771	2·525	2·550	10·09	10·05	42,460	2·488	4·273	58·22	17·00	43·24	39·31

APPENDIX C.—TABLE 14.—SUMMARY OF EXPERIMENTS, GREAT WESTERN COLLIERY—GUIBAL FAN.

1	6·750	2,406	0·050	0·000	4·085	?	16,572	2·501	4·407	56·75	0·019	2·86	0·70
2	47·250	23,033	2·580	−0·010	5·459	?	23,271	2·633	4·400	59·84	9·356	88·21	10·60
3	47·375	35,011	2·540	0·000	8·352	?	35,280	2·579	4·381	58·86	13·999	94·68	14·78
4	47·875	38,517	2·590	−0·020	9·091	?	38,404	2·575	4·386	58·70	15·704	98·55	15·93
5	48·000	51,543	2·590	0·010	12·166	?	51,263	2·562	4·378	58·52	21·106	100·99	20·80
6	48·000	53,898	2·570	−0·020	12·776	?	53,606	2·542	4·380	58·03	21·806	102·84	21·20
7	50·875	224,088	2·940	2·230	49·712	57·079	210,279	2·588	4·399	58·83	103·734	191·29	54·22
8	46·625	210,396	2·440	1·850	51·301	58·830	215,427	2·558	4·398	58·16	80·831	146·12	55·32
9	46·875	217,792	2·490	1·790	52·526	61·978	221,811	2·582	4·401	58·66	85·387	158·07	54·02
10	33·750	160,823	1·290	0·900	53·834	64·504	227,487	2·581	4·396	58·71	32·659	70·41	46·38
11	41·375	338,819	1·550	0·420	103·898	199·506	390,941	2·063	4·412	46·75	82·690	161·72	51·13

APPENDIX C.—TABLE 15.—SUMMARY OF EXPERIMENTS, PELTON COLLIERY—GUIBAL FAN.

No. of Experiment.	Observations.				Calculations.								
	Mean Revolutions of Fan per Minute.	Mean Volume of Air per Minute.	Depression at		Equivalent Orifice.		Volume of Air per Minute at Normal Velocity.	Depression at Inlet at Normal Velocity.	Theoretical Depression at Normal Velocity.	Manometric Efficiency at Inlet of Fan.	Useful Effect in Air at Inlet of Fan.	Motive Power of Engine.	Motive Power utilized at Inlet of Fan.
			Inlet.	Drift.	Inlet Depression.	Drift Depression.							
		Cubic Feet.	Inches.	Inches.	Sq. Feet.	Sq. Feet.	Cubic Feet.	Inches.	Inches.	Per Cent.	Horsepower.	Horsepower.	Per Cent.
1	54·125	28,232	2·860	2·820	6·05	6·53	27,671	2·747	4·595	59·78	12·72	68·87	18·47
2	53·250	27,957	2·790	2·700	6·54	6·64	27,852	2·769	4·601	60·18	12·28	65·14	18·86
3	53·250	42,917	2·850	2·800	9·89	9·98	42,755	2·828	4·599	61·49	19·27	68·60	28·09
4	53·375	46,882	2·729	2·698	10·95	11·11	46,596	2·695	4·595	58·65	20·16	70·41	28·63
5	61·250	170,960	3·650	3·679	34·81	34·59	148,072	2·738	4·580	59·78	98·34	174·95	56·21
6	52·375	154,154	2·694	2·631	36·54	36·93	156,140	2 764	4·587	60·25	65·45	116·03	56·40
7	32·625	96,592	1·050	1·047	36·86	36·86	157,063	2·776	4·629	59·97	15·98	33·65	47·49
8	51·375	176,104	2·570	2·533	42·75	43·03	181,845	2·740	4·590	59·69	71·33	123·48	57·76
9	51·875	254,516	1·978	1·833	70·79	73·56	260,280	2·068	4·652	44·45	79·34	184·36	43·03

APPENDIX C.—TABLE 16.—SUMMARY OF EXPERIMENTS, WINGATE GRANGE COLLIERY—GUIBAL FAN.

1	40·500	25,150	1·595	1·534	7·66	7·76	32,943	2·736	4·448	61·51	6·32	28·101	22·49
2	39·875	25,945	1·553	1·486	7·95	8·13	34,517	2·748	4·470	61·48	6 35	27·974	22·69
3	39·625	62,543	1·536	1·519	19·28	19·39	83,732	2·753	4·436	62·06	15·14	28·654	52·83
4	52·250	146,611	2·640	2·335	34·68	36·88	148,844	2·721	4·483	60·70	61·01	110·463	55·23
5	42·250	126,235	1·710	1·519	37·06	39·36	158,503	2·696	4·470	60·31	34·02	63·977	54·73
6	35·375	110,898	1·182	1·069	39·32	41·72	166,307	2·684	4·508	58·96	20·66	39·661	52·09
7	41·250	136,755	1·614	1·440	41·47	43·88	175,875	2·669	4·501	59·80	34·79	67·572	51·48
8	25·875	93,395	0·610	0·535	45·91	48·76	191,482	2·564	4·458	57·51	8·98	17·662	50·83
9	37·875	180,469	1·123	0·990	65·50	69·85	252,775	2·203	4·500	48·96	31·94	69·083	46·23

APPENDIX C.—TABLE 17.—SUMMARY OF EXPERIMENTS, GREAT WESTERN COLLIERY—SCHIELE FAN.

No. of Experiment.	Observations.				Calculations.								
	Mean Revolutions of Fan per Minute.	Mean Volume of Air per Minute.	Depression at		Equivalent Orifice.		Volume of Air per Minute at Normal Velocity.	Depression at Inlet at Normal Velocity.	Theoretical Depression at Normal Velocity.	Manometric Efficiency at Inlet of Fan.	Useful Effect in Air at Inlet of Fan.	Motive Power of Engine.	Motive Power utilized at Inlet of Fan.
			Inlet.	Drift.	Inlet Depression.	Drift Depression.							
		Cubic Feet.	Inches	Inches.	Sq. Feet.	Sq. Feet.	Cubic Feet.	Inches.	Inches.	Per Cent.	Horsepower.	Horsepower.	Per Cent.
1	112·875	23,924	1·670	−0·210	7·081	?	26,542	2·055	4·446	46·08	6·290	28·82	21·82
2	121·875	33,079	1·970	−0·050	8·975	?	33,989	2·079	4·409	47·15	10·254	36·88	27·80
3	133·750	36,415	2·240	−0·010	9·292	?	34,095	1·963	4·436	44·25	12·843	46·59	27·56
4	138·000	48,337	2·410	−0·030	11·872	?	43,139	1·984	4·422	44·86	18·335	53·58	34·22
5	124·000	44,919	1·990	−0·050	12·157	?	43,751	2·029	4·433	45·77	14·072	41·17	34·18
6	171·625	233,424	3·840	3·040	45·497	51·184	170,323	2·044	4·417	46·27	141·079	210·04	67·16
7	139·875	193,021	2·530	1·990	46·350	52·243	172,811	2·028	4·425	45·83	76·862	129·07	59·55
8	120·625	176,868	1·870	1·410	49·318	56·751	183,620	2·015	4·414	45·65	52·056	90·35	57·61
9	124·875	187,366	2·020	1·520	50·355	58·099	188,039	2·031	4·437	45·78	59·570	100·67	59·17
10	83·125	126,457	0·900	0·660	50·904	59·367	190,510	2·042	4·422	46·18	17·909	31·65	56·58
11	133·500	320,658	1·570	0·440	97·787	184·879	300,794	1·381	4·432	31·16	79·206	149·65	52·92

APPENDIX C.—TABLE 18.—SUMMARY OF EXPERIMENTS, NATIONAL COLLIERY—SCHIELE FAN.

1	123·875	10,785	2·320	−0·360	2·670	?	10,902	2·371	4·318	54·91	3·93	41·694	9·42
2	137·500	24,146	3·100	−0·030	5·174	?	21,991	2·571	4·328	59·40	11·78	55·344	21·28
3	123·875	22,415	2·560	−0·240	5·276	?	22,660	2·616	4·312	60·67	9·03	49·638	18·19
4	126·750	29,860	2·460	−0·050	7·189	?	29,502	2·401	4·335	55·38	11·56	53·562	21·58
5	127·500	34,447	2·460	−0·120	8·287	?	33,833	2·379	4·330	54·94	13·33	54·107	24·63
6	127·000	131,834	2·000	1·630	35·353	39·157	129,996	1·944	4·373	44·45	41·52	100·749	41·21
7	164·750	171,111	3·870	2·850	35·385	38·476	130,065	1·947	4·383	44·42	90·81	214·405	42·35
8	119·375	142,458	1·730	1·360	41·175	46·851	149,445	1·903	4·394	43·31	38·82	96·750	40·12
9	78·250	101,572	0·750	0·600	44·391	49·752	162,554	1·920	4·355	44·09	11·99	29·527	40·60
10	120·625	190,427	1·660	1·200	56·331	66·251	197,697	1·789	4·417	37·58	49 80	128·790	38·66

APPENDIX C.—TABLE 19.—SUMMARY OF EXPERIMENTS, TOWNELEY COLLIERY—SCHIELE FAN.

No. of Experiment.	Observations.				Calculations.									
	Mean Revolutions of Fan per Minute.	Mean Volume of Air per Minute.	Depression at		Equivalent Orifice.		Volume of Air per Minute at Normal Velocity.	Depression at Inlet at Normal Velocity.	Theoretical Depression at Normal Velocity.	Manometric Efficiency at Inlet of Fan.	Useful Effect in Air at Inlet of Fan.	Motive Power of Engine.	Motive Power utilized at Inlet of Fan.
			Inlet.	Drift.	Inlet Depression.	Drift Depression.							
		Cubic Feet.	Inches.	Inches.	Sq. Feet.	Sq. Feet.	Cubic Feet.	Inches.	Inches.	Per Cent.	Horsepower.	Horsepower.	Per Cent.
1	160·375	16,944	2·200	0·030	4·400	?	16,815	2·176	4·471	48·67	5·88	30·90	19·02
2	170·500	19,904	2·490	0·010	4·480	?	18,579	2·170	4·476	48·48	7·80	36·21	21·54
3	152·625	25,632	2·100	0·110	6·788	?	26,728	2·283	4·475	50·95	8·47	30·99	27·33
4	165·500	32,480	2·440	0·030	7·990	?	31,234	2·256	4·489	50·25	12·47	39·29	31·75
5	176·250	65,456	2·600	2·320	15·650	16·543	59,190	2·126	4·504	47·21	26·80	54·05	49·57
6	160·250	59,904	2·160	1·960	15·714	16·495	59,494	2·130	4·500	47·33	20·38	42·72	47·70
7	126·250	48,688	1·330	1·210	16·283	17·056	61,377	2·114	4·502	46·97	10·19	25·14	40 53
8	167·000	89,322	2·180	1·970	23·410	24·610	85,125	1·977	4·493	44·00	30·63	53·03	57·76
9	148·250	154,768	1·250	1·030	53·373	58·694	166,151	1·440	4·504	31·97	30·46	59·21	51·44

APPENDIX C.—TABLE 20.—SUMMARY OF EXPERIMENTS, WINGATE GRANGE COLLIERY—SCHIELE FAN.

1	160·625	20,716	2·170	1·997	5·37	5·59	20,525	2·130	4·425	48·13	7·08	38·613	18·33
2	160·250	26,131	2·120	2·014	6·85	7·03	25,951	2·091	4·428	47·23	8·73	40·445	21·58
3	152·000	34,801	1·936	1·702	9·55	10·19	36,438	2·122	4·424	47·97	10·61	39·028	27·18
4	161·500	38,646	2·175	1·852	10·01	10·85	38,088	2·112	4·433	47·65	13·24	42·941	30·83
5	141·250	111,035	1·415	0·669	35·73	52·08	125,106	1·796	4·444	40·41	24·76	56·940	43·48
6	88·375	80,432	0·534	0·196	42·16	69·52	144,845	1·731	4·398	39·36	6·77	16·820	40·24
7	134·125	126,572	1·245	0·261	43·51	95·31	150,113	1·753	4·459	39·31	24·84	56·812	43·72

APPENDIX C.—TABLE 21.—SUMMARY OF EXPERIMENTS, CWMAMAN COLLIERY—WADDLE FAN.

No. of Experiment.	Observations.				Calculations.								
	Mean Revolutions of Fan per Minute.	Mean Volume of Air per Minute.	Depression at		Equivalent Orifice.		Volume of Air per Minute at Normal Velocity.	Depression at Inlet at Normal Velocity.	Theoretical Depression at Normal Velocity.	Manometric Efficiency at Inlet of Fan.	Useful Effect in Air at Inlet of Fan.	Motive Power of Engine.	Motive Power utilized at Inlet of Fan.
			Inlet.	Drift.	Inlet Depression.	Drift Depression.							
		Cubic Feet.	Inches.	Inches.	Sq. Feet.	Sq. Feet.	Cubic Feet.	Inches.	Inches.	Per Cent.	Horsepower.	Horsepower.	Per Cent.
1	109·525	134,566	5·556	5·526	21·55	21·59	78,214	1·877	4·331	43·33	117·78	233·04	50·50
2	43·146	64,871	0·933	0·922	25·24	25·46	95,680	2·030	4·313	47·07	9·53	20·99	45·40
3	63·663	94,592	1·876	1·827	26·04	26·37	94,592	1·876	4·307	43·55	27·95	51·75	54·00
4	64·569	141,544	1·885	1·815	38·97	39·66	139,550	1·832	4·331	42·30	42·03	72·75	57·77

APPENDIX C.—TABLE 22.—SUMMARY OF EXPERIMENTS, NATIONAL COLLIERY—WADDLE FAN.

1	39·375	19,518	1·780	−0·400	5·550	?	21,037	2·067	4·376	47·23	5·47	64·470	8·48
2	45·125	25,312	2·500	−0·060	6·062	?	23,805	2·211	4·353	50·79	9·96	83·956	11·86
3	45·375	27,928	2·290	−0·150	6·986	?	27,325	2·003	4·358	45·95	10·07	85·729	11·74
4	42·000	30,262	1·980	−0·050	8·125	?	30,579	2·021	4·390	46·03	9·43	73·424	12·89
5	43·000	36,218	2·110	−0·140	9·443	?	35,746	2·055	4·358	47·15	12·03	80·597	14·92
6	41·750	115,778	1·680	1·650	33·979	34·286	117,691	1·735	4·398	39·45	30·64	128·524	23·84
7	54·750	158,234	3·010	3·000	34·504	34·816	122,656	1·808	4·387	41·21	75·02	265·035	28·35
8	40·375	125,235	1·630	1·620	37·152	37·276	131,640	1·809	4·358	41·51	32·16	106·705	30·14
9	43·000	136,502	1·770	1·740	38·965	39·316	134,724	1·724	4·378	39·37	38·05	132·390	28·74
10	26·375	91,914	0·660	0·650	42·965	43·282	147,898	1·708	4·372	39·06	9·55	40·579	23·53
11	39·875	178,878	1·490	1·470	55·795	56·179	190,385	1·687	4·400	38·34	41·99	130·975	32·06

APPENDIX C.—TABLE 23.—SUMMARY OF EXPERIMENTS, PELTON COLLIERY—WADDLE TYPE OF FAN.

No. of Experiment.	Observations.				Calculations.								
	Mean Revolutions of Fan per Minute.	Mean Volume of Air per Minute.	Depression at		Equivalent Orifice.		Volume of Air per Minute at Normal Velocity.	Depression at Inlet at Normal Velocity.	Theoretical Depression at Normal Velocity.	Manometric Efficiency at Inlet of Fan.	Useful Effect in Air at Inlet of Fan.	Motive Power of Engine.	Motive Power utilized at Inlet of Fan.
			Inlet.	Drift.	Inlet Depression.	Drift Depression.							
		Cubic Feet.	Inches.	Inches	Sq. Feet.	Sq. Feet.	Cubic Feet.	Inches.	Inches.	Per Cent.	Horsepower.	Horsepower.	Per Cent.
1	65·000	22,801	2·400	2·120	5·72	6·09	21,201	2·075	4·588	45·22	8·62	49·07	17·56
2	64·000	24,503	2·400	2·121	6·15	6·53	23,140	2·140	4·582	46·70	9·26	47·33	19·56
3	66·000	37,052	2·521	2·236	9·07	9·62	33,930	2·114	4·581	46·14	14·72	58·16	25·30
4	66·250	47,383	2·505	2·241	11·63	12·31	44,887	2·084	4·583	45·47	18·70	60·08	31·12
5	41·500	85,306	1·000	0·950	33·25	34·09	124,238	2·121	4·603	46·08	13·44	36·77	36·55
6	57·750	121,605	1·893	1·840	34·41	34·96	127,269	2·073	4·612	44·95	36·28	86·10	42·13
7	55·750	132,531	1·780	1·700	38·81	39·66	143,680	2·092	4·628	45·20	37·18	85·09	43·69
8	45·750	175,084	1·100	1·000	65·47	68·72	231,302	1·919	4·668	41·11	30·35	71·12	42·67

APPENDIX C.—TABLE 24.—SUMMARY OF EXPERIMENTS, TOWNELEY COLLIERY—WADDLE FAN.

1	39·375	11,160	1·520	0·080	3·432	?	13,540	2·284	4·364	51·19	2·67	32·54	8·20
2	32·750	9,856	1·050	—0·060	3·685	?	14,367	2·231	4·454	50·07	1·63	24·83	6·24
3	33·500	20,984	1·420	0·000	6·752	?	26,020	2·183	4·456	48·99	4·69	33·53	13·98
4	39·375	21,952	1·470	0·020	6·900	?	26,615	2·161	4·466	48·39	5·08	35·45	14·35
5	40·250	50,400	1·490	1·400	15·640	16·342	59,788	2·096	4·463	46·97	11·24	43·71	25·64
6	34·625	42,864	1·080	0·990	15·666	16·539	59,099	2·053	4·461	46·02	7·45	33·84	21·54
7	20·750	27,504	0·420	0·390	16·281	16·858	63,279	2·223	4·455	49·91	1·82	14·86	12·24
8	39·750	73,568	1·400	1·340	24·004	25·230	88,355	2·020	4·462	45·27	16·21	46·43	34·91
9	36·625	156,256	1·090	1·050	57·440	58·530	203,676	1·852	4·479	41·35	26·82	53·55	50·08

APPENDIX D.—TABLE 25.—CWMAMAN COLLIERY, GUIBAL FAN.

No. of Experiment.	Equivalent Orifice.	Volumes of Air per Minute at Normal Velocity.	Squares of Volumes.	Depressions.			
				Theoretical	Observed.	Calculated.	Difference.
	Sq. Ft.	Cubic Feet.		Inches.	Inches.	Inches.	Inches.
1	4·04	17,212	296,252,944	4·276	2·552	2·593	−0·041
2	4·86	21,015	441,630,225	4·283	2·633	2·587	+0·046
3	9·03	38,635	1,492,663,225	4·281	2·572	2·539	+0·033
4	10 09	42,460	1,802,851,600	4·273	2·488	2·525	−0·037

$$h = 2{\cdot}606 - 0{\cdot}000{,}000{,}000{,}045{,}000\ V^2.$$

APPENDIX D.—TABLE 26.—GREAT WESTERN COLLIERY, GUIBAL FAN.

No. of Experiment.	Equivalent Orifice.	Volumes of Air per Minute at Normal Velocity.	Squares of Volumes.	Depressious.			
				Theoretical.	Observed.	Calculated.	Difference.
	Sq. Ft.	Cubic Feet.		Inches.	Inches	Inches.	Inches.
1	4·085	16,572	274,631,184	4·407	2·501	2·634	−0·133
2	5·459	23,271	541,539,441	4·100	2·633	2·633	0·000
3	8·352	35,280	1,244,678,400	4·381	2·579	2·631	−0·052
4	9·091	38,404	1,474,867,216	4·386	2·575	2·630	−0·055
5	12·166	51,263	2,627,895,169	4·378	2·562	2·626	−0·064
6	12·776	53,606	2,873,603,236	4·380	2·542	2·625	−0·083
7	49·712	210,279	44,217,257,841	4·399	2·588	2·470	+0·118
8	51·301	215,427	46,408,792,329	4·398	2·558	2·462	+0·096
9	52·526	221,811	49,200,119,721	4·401	2·582	2·451	+0·131
10	53·834	227,487	51,750,335,169	4·396	2·581	2·442	+0·139
11	103·898	390,941	152,834,865,481	4·412	2·063	2·063	0·000

$$h = 2{\cdot}635 - 0{\cdot}000{,}000{,}000{,}003{,}742\ V^2.$$

APPENDIX D.—TABLE 27.—PELTON COLLIERY, GUIBAL FAN.

No. of Experiment.	Equivalent Orifice.	Volumes of Air per Minute at Normal Velocity.	Squares of Volumes.	Depressions.			
				Theoretical.	Observed.	Calculated.	Difference.
	Sq. Ft.	Cubic Feet.		Inches.	Inches.	Inches.	Inches.
1	6·05	27,671	765,684,241	4·595	2·747	3·047	−0·300
2	6·54	27,852	775,733,904	4·601	2·769	3·047	−0·278
3	9·89	42,755	1,827,990,025	4·599	2·828	3·032	−0·204
4	10·95	46,596	2,171,187,216	4·595	2·695	3·027	−0·332
5	34·81	148,072	21,925,317,184	4·580	2·738	2·738	0·000
6	36·54	156,140	24,379,699,600	4·587	2·764	2·702	+0·062
7	36·86	157,063	24,668,785,969	4·629	2·776	2·699	+0·077
8	42·75	181,845	33,067,604,025	4·590	2·740	2·576	+0·164
9	70·79	260,280	67,745,678,400	4·652	2·068	2·068	0·000

$$h = 3{\cdot}058 - 0{\cdot}000{,}000{,}000{,}014{,}600\ V^2.$$

APPENDIX D.—TABLE 28.—WINGATE GRANGE COLLIERY, GUIBAL FAN.

No. of Experiment.	Equivalent Orifice.	Volumes of Air per Minute at Normal Velocity.	Squares of Volumes.	Depressions.			
				Theoretical.	Observed.	Calculated.	Difference.
	Sq Ft.	Cubic Feet.		Inches.	Inches.	Inches.	Inches.
1	7·66	32,943	1,085,241,249	4·448	2·736	2·983	—0·247
2	7·95	34,517	1,191,423,289	4·470	2·748	2·981	—0·233
3	19·28	83,732	7,011,047,824	4·436	2·753	2·909	—0·156
4	34·68	148,844	22,154,536,336	4·483	2·721	2·721	0·000
5	37·06	158,503	25,123,201,009	4·470	2·696	2·685	+0·011
6	39·32	166,307	27,658,018,249	4·508	2·684	2·653	+0·031
7	41·47	175,875	30,932,015,625	4·501	2·669	2·613	+0·056
8	45·91	191,482	36,665,356,324	4·458	2·564	2·541	+0·023
9	65·50	252,775	63,895,200,625	4·500	2·203	2·203	0·000

$$h = 2{\cdot}996 - 0{\cdot}000{,}000{,}000{,}012{,}400\ V^2.$$

APPENDIX D.—TABLE 29.—GREAT WESTERN COLLIERY, SCHIELB FAN.

No. of Experiment	Equivalent Orifice.	Volumes of Air per Minute at Normal Velocity.	Squares Volumes.	Depressions.			
				Theoretical.	Observed.	Calculated.	Difference.
	Sq. Ft.	Cubic Feet.		Inches.	Inches.	Inches.	Inches.
1	7·081	26,542	704,477,764	4·446	2·055	2·082	—0·027
2	8·975	33,989	1,155,252,121	4·409	2·079	2·079	0·000
3	9·292	34,095	1,162,469,025	4·436	1·963	2·079	—0·116
4	11·872	43,139	1,860,973,321	4·422	1·984	2·073	—0·089
5	12·157	43,751	1,914,150,001	4·433	2·029	2·073	—0·044
6	45·497	170,323	29,009,924,329	4·417	2·044	1·856	+0·188
7	46·350	172,811	29,863,641,721	4·425	2·028	1·849	+0·179
8	49·318	183,620	33,716,304,400	4·414	2·015	1·818	+0·197
9	50·355	188,039	35,358,665,521	4·437	2·031	1·805	+0·226
10	50·904	190,510	36,294,060,100	4·422	2·042	1·798	+0·244
11	97·787	300,794	90,477,030,436	4·432	1·881	1·364	+0·017

$$h = 2{\cdot}088 - 0{\cdot}000{,}000{,}000{,}008{,}000\ V^2.$$

APPENDIX D.—TABLE 30.—NATIONAL COLLIERY, SCHIELE FAN.

No. of Experiment.	Equivalent Orifice.	Volumes of Air per Minute at Normal Velocity.	Squares of Volumes.	Depressions.			
				Theoretical.	Observed.	Calculated.	Difference.
	Sq. Ft.	Cubic Feet.		Inches.	Inches.	Inches.	Inches.
1	2·670	10,902	118,853,604	4·318	2·371	2·418	−0·047
2	5·174	21,991	483,604,081	4·328	2·571	2·410	+0·161
3	5·276	22,660	513,475,600	4·312	2·616	2·409	+0·207
4	7·189	29,502	870,368,004	4·335	2·401	2·401	0·000
5	8·287	33,833	1,144,671,889	4·330	2·379	2·395	−0·016
6	35·353	129,996	16,898,960,016	4·373	1·944	2·029	—0·085
7	35·385	130,065	16,916,904,225	4·383	1·947	2·028	—0·081
8	41·175	149,445	22,333,808,025	4·394	1·903	1·903	0·000
9	44·391	162,554	26,423,802,916	4·355	1·920	1·808	+0·112
10	56·331	197,697	39,084,103,089	4·417	1·789	1·515	+0·274

$$h = 2{\cdot}421 - 0{\cdot}000{,}000{,}000{,}023{,}200\ V^2.$$

APPENDIX D.—TABLE 31.—TOWNELEY COLLIERY, SCHIELE FAN.

No. of Experiment.	Equivalent Orifice.	Volumes of Air per Minute at Normal Velocity.	Squares of Volumes.	Depressions.			
				Theoretical.	Observed.	Calculated.	Difference.
	Sq. Ft.	Cubic Feet.		Inches.	Inches.	Inches.	Inches.
1	4·400	16,815	282,744,225	4·471	2·176	2·241	−0·065
2	4·480	18,579	345,179,241	4·476	2·170	2·239	−0·069
3	6·788	26,728	714,385,984	4·475	2·283	2·228	+0·055
4	7·990	31,234	975,562,756	4·489	2·256	2·218	+0·038
5	15·650	59.190	3,503,456,100	4·504	2·126	2·141	−0·015
6	15·714	59,494	3,539,536,036	4·500	2·130	2·140	−0·010
7	16·283	61,377	3,767,136,129	4·502	2·114	2·133	−0·019
8	23·410	85,125	7,246,265.625	4·493	1·977	2·024	−0·047
9	53·373	166,151	27,606,154,801	4·504	1·440	1·390	+0·050

$$h = 2·250 - 0·000,000,000,031,150\ V^2.$$

APPENDIX D.—TABLE 32.—WINGATE GRANGE COLLIERY, SCHIELE FAN.

No. of Experiment.	Equivalent Orifice.	Volumes of Air per Minute at Normal Velocity.	Squares of Volumes.	Depressions.			
				Theoretical.	Observed.	Calculated.	Difference.
	Sq. Ft.	Cubic Feet.		Inches.	Inches.	Inches.	Inches.
1	5·37	20,525	421,275,625	4·425	2·130	2·130	0·000
2	6·85	25,951	673,454,401	4·428	2·091	2·125	−0·034
3	9·55	36,438	1,327,727,844	4·424	2·122	2·112	+0·010
4	10·01	38,083	1,450,314,889	4·433	2·112	2·110	+0·002
5	35·73	125,106	15,651,511,236	4·444	1·796	1·834	−0·038
6	42·16	144,845	20,980,074,025	4·398	1·731	1·731	0·000
7	43·51	150,113	22,533,912,769	4·459	1·753	1·701	+0·052

$$h = 2·138 - 0·000,000,000,019,400\ V^2.$$

APPENDIX D.—TABLE 33.—CWMAMAN COLLIERY, WADDLE FAN.

No. of Experiment.	Equivalent Orifice.	Volumes of Air per Minute at Normal Velocity.	Squares of Volumes.	Depressions.			
				Theoretical.	Observed.	Calculated.	Difference.
	Sq. Ft.	Cubic Feet.		Inches.	Inches.	Inches.	Inches.
1	21·55	78,214	6,117,429,796	4·331	1·877	1·888	−0·011
3	26·04	94,592	8,947,646,464	4·307	1·876	1·876	0·000
2	25·24	95,680	9,154,662,400	4·313	2·030	1·875	+0·155
4	38·97	139,550	19,474,202,500	4·331	1·832	1·832	0·000

$$h = 1·913 - 0·000,000,000,004,179\ V^2.$$

APPENDIX D.—TABLE 34.—NATIONAL COLLIERY, WADDLE FAN.

No. of Experiment.	Equivalent Orifice.	Volumes of Air per Minute at Normal Velocity.	Squares of Volumes.	Depressions.			
				Theoretical.	Observed.	Calculated.	Difference.
	Sq. Ft.	Cubic Feet.		Inches.	Inches.	Inches.	Inches.
1	5·550	21,037	442,555,369	4·376	2·067	2·005	+0·062
2	6·062	23,805	566,678,025	4·353	2·211	2·004	+0·207
3	6·986	27,325	746,655,625	4·358	2·003	2·003	0·000
4	8·125	30,579	935,075,241	4·390	2·021	2·001	+0·020
5	9·443	35,746	1,277,776,516	4·358	2·055	1·998	+0·057
6	33·979	117,691	13,851,171,481	4·398	1·735	1·886	−0·151
7	34·504	122,656	15,044,494,336	4·387	1·808	1·875	−0·067
8	37·152	131,640	17,329,089,600	4·358	1·809	1·855	−0·046
9	38·965	134,724	18,150,556,176	4·378	1·724	1·848	−0·124
10	42·965	147,898	21,873,818,404	4·372	1·708	1·815	−0·107
11	55·795	190,385	36,246,418,225	4·400	1·687	1·687	0·000

$$h = 2{\cdot}009 - 0{\cdot}000,000,000,008,900\ V^2.$$

APPENDIX D.—TABLE 35.—PELTON COLLIERY, WADDLE FAN.

o. of Experiment.	Equivalent Orifice.	Volumes of Air per Minute at Normal Velocity.	Squares of Volumes.	Depressions.			
				Theoretical.	Observed.	Calculated.	Difference.
	Sq. Ft.	Cubic Feet.		Inches.	Inches.	Inches.	Inches.
1	5·72	21,201	449,482,401	4·588	2·075	2·140	−0·065
2	6·15	23,140	535,459,600	4·582	2·140	2·140	0·000
3	9·07	33,930	1,151,244,900	4·581	2·114	2·137	−0·023
4	11·63	44,887	2,014,842,769	4·583	2·084	2·134	−0·050
5	33·25	124,238	15,435,080,644	4·603	2·121	2·078	+0·043
6	34·41	127,269	16,197,398,361	4·612	2·073	2·075	−0·002
7	38·81	143,680	20,643,942,400	4·628	2·092	2·055	+0·037
8	65·47	231,302	53,500,615,204	4·668	1·919	1·919	0·000

$$h = 2{\cdot}142 - 0{\cdot}000,000,000,004,170\ V^2.$$

APPENDIX D.—TABLE 36.—TOWNELEY COLLIERY, WADDLE FAN.

No. of Experiment.	Equivalent Orifice.	Volumes of Air per Minute at Normal Velocity.	Squares of Volumes.	Depressions.			
				Theoretical.	Observed.	Calculated.	Difference.
	Sq. Ft.	Cubic Feet.		Inches.	Inches.	Inches.	Inches.
1	3·432	13,540	183,331,600	4·364	2·234	2·184	+0·050
2	3·685	14,367	206,410,689	4·454	2·231	2·183	+0·048
3	6·752	26,020	677,040,400	4·456	2·183	2·180	+0·003
4	6·900	26,615	708,358,225	4·466	2·161	2·179	−0·018
6	15·666	59,099	3,492,691,801	4·461	2·053	2·157	−0·104
5	15·640	59,788	3,574,604,944	4·463	2·096	2·156	−0·060
7	16·281	63,279	4,004,231,841	4·455	2·223	2·153	+0·070
8	24·004	88,355	7,806,606,025	4·462	2·020	2·122	−0·102
9	57·440	203,676	41,483,912,976	4·479	1·852	1·850	+0·002

$$h = 2{\cdot}185 - 0{\cdot}000,000,000,008,080\ V^2.$$

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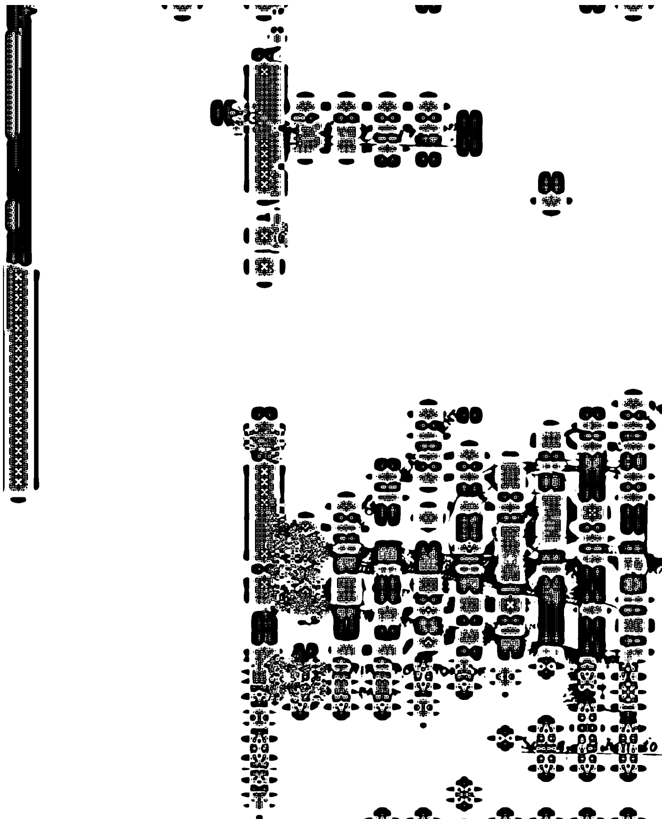
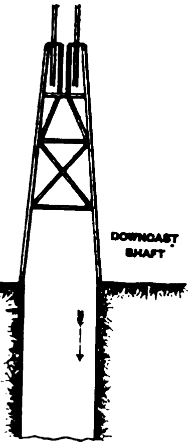
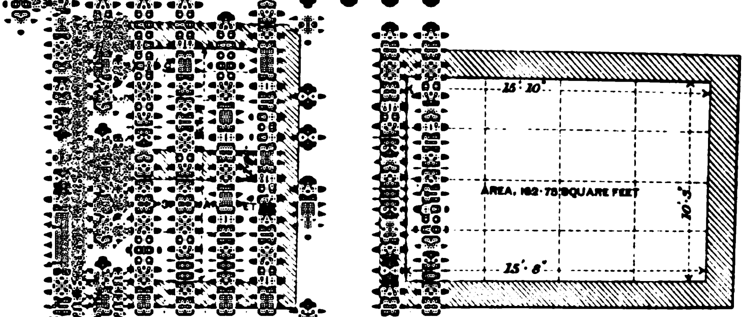



SHAFT
DOWNCAST SHAFT

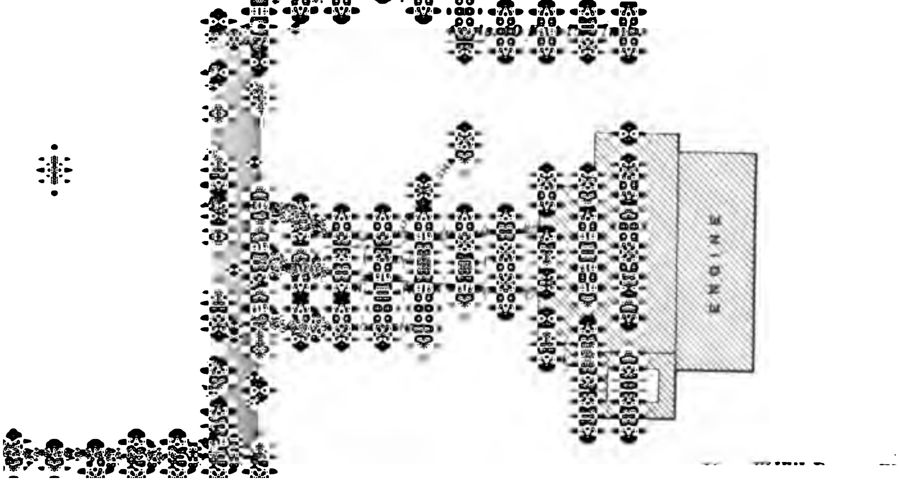
to 1 Inch.

LLIERY.

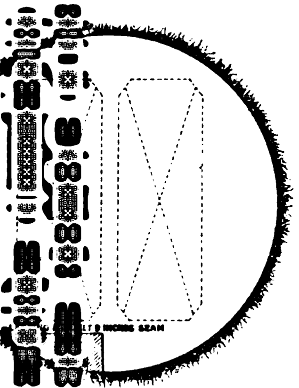

15' 10"
AREA, 162·75 SQUARE FEET
10' 3"
15' 8"

9.—CROSS-SECTION OF PLACE OF AIR-MEASUREMENT

CHIMNEY OF SCHIELE FAN.

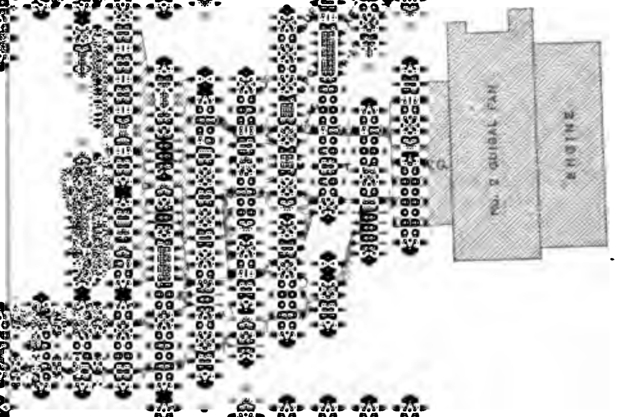


Vol XVII. Plate XVI.



...LT 8 INCHES SEAM

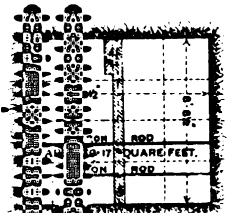
...WING OBSTRUCTIONS IN THE
...NCAST SHAFT,
...EPTH OF 1,212 FEET.



NO. 2 GUIBAL FAN
ENGINE

...NGEMENTS.

Scale, 40 Feet to 1 Inch.

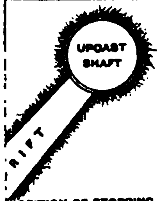


...ON ROD
AREA 17 SQUARE FEET.
...ON ROD

...SECTION OF PLACE OF
...EASUREMENT
...TO WADDLE FAN.

Vol XLVIII Plate X.

INGATE GRANGE COLLIERY.


UPCAST SHAFT
RIFT

POSITION OF STOPPING AND RESTRICTED ORIFICES.

Fig. 2

OF AIR-MEASUREMENT

O

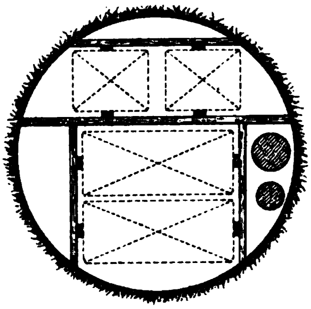
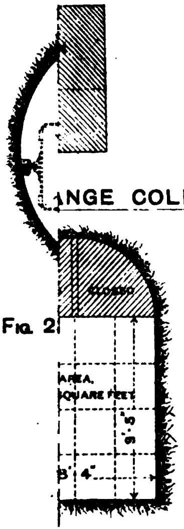


Fig. 30.—Plan showing obstructions in the Lady (downcast) shaft.


AREA.
SQUARE FEET
5'.8"
8'4"

NGE COLLIERY.

Fig. 2

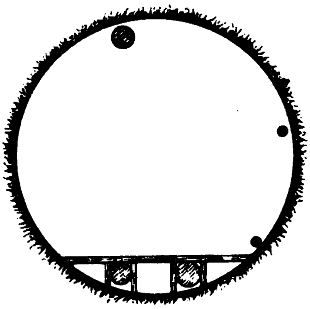
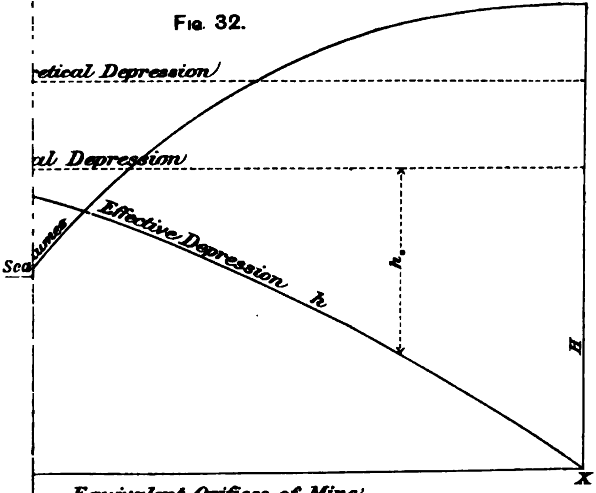


Fig. 31.—Plan showing obstructions in the Lord (upcast) shaft.

Scale. 10 Feet to 1 Inch.

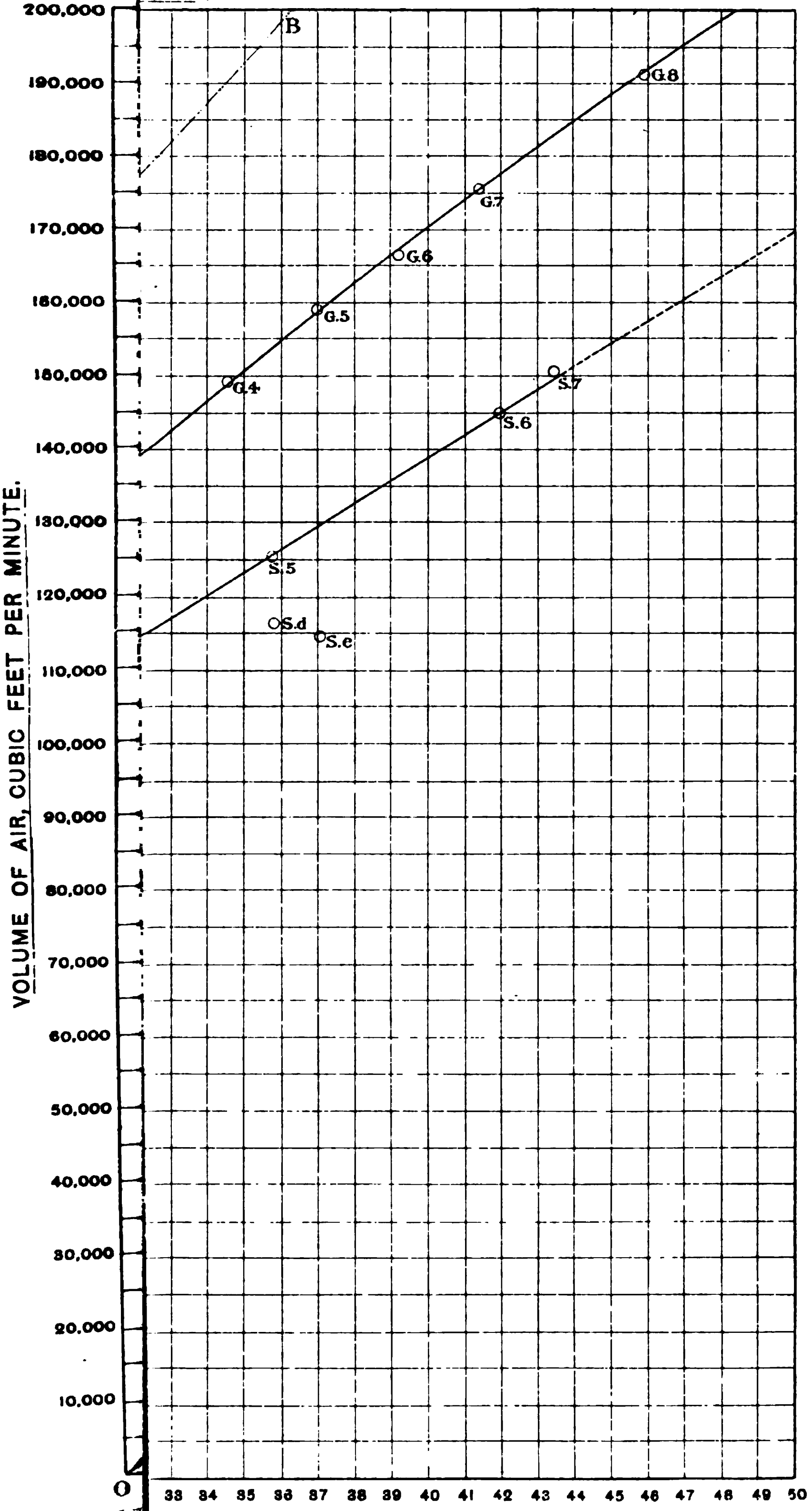
SECTION OF PLACE OF ASUREMENT
O SCHIELE FAN.

Fig. 32.



The Institut[illegible] [illegible]utors."

VOL. XVII, PLATE XXIII.



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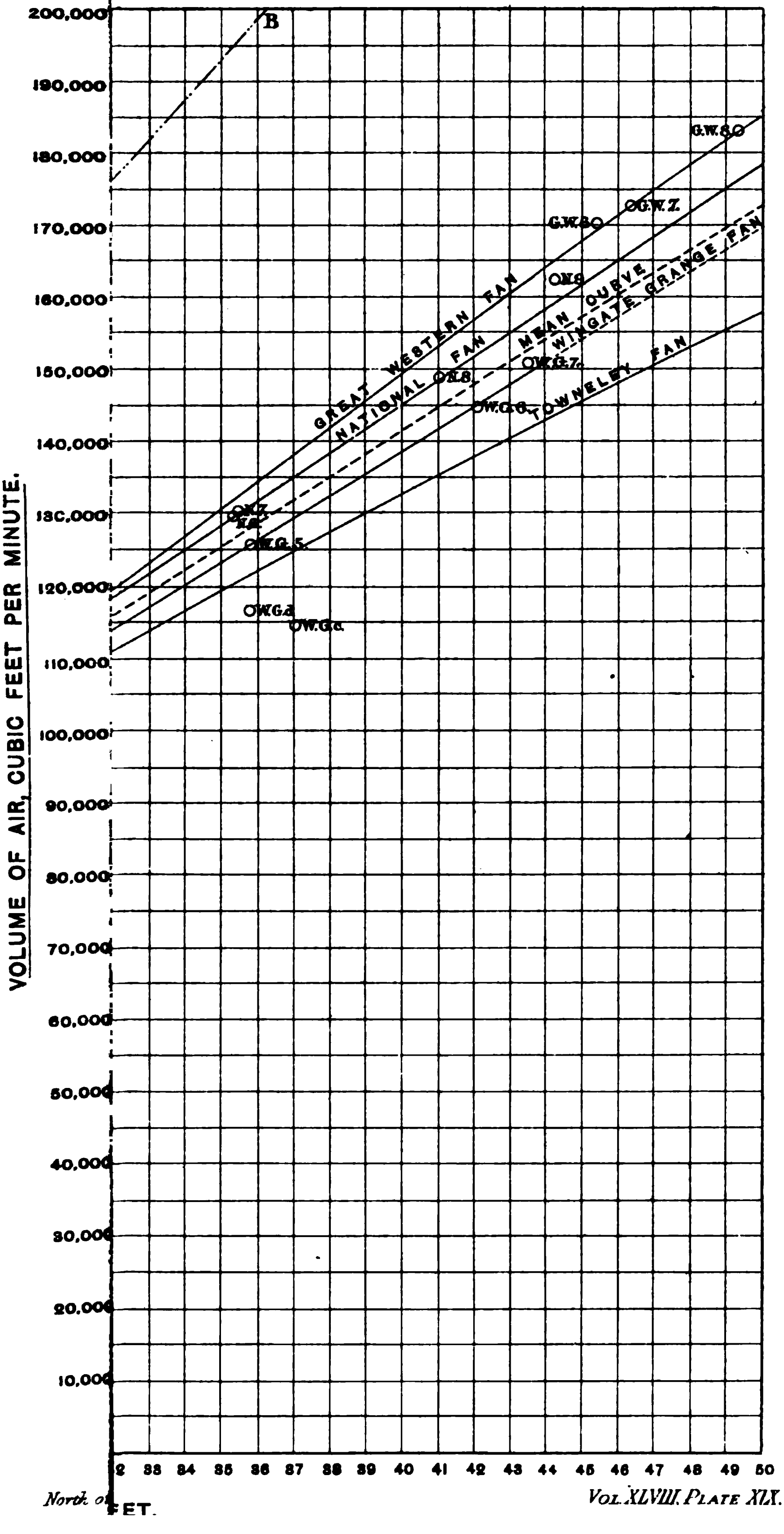
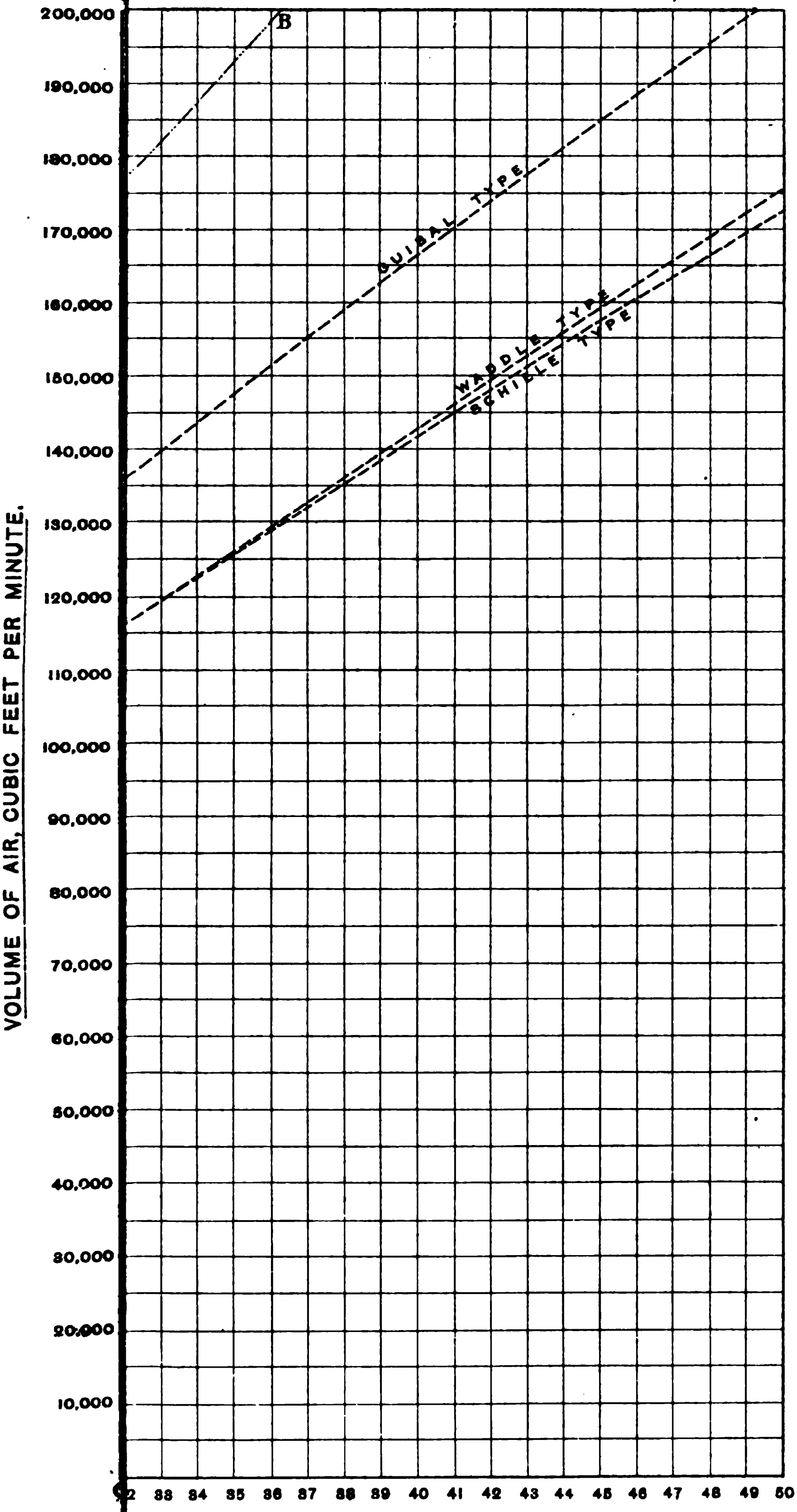
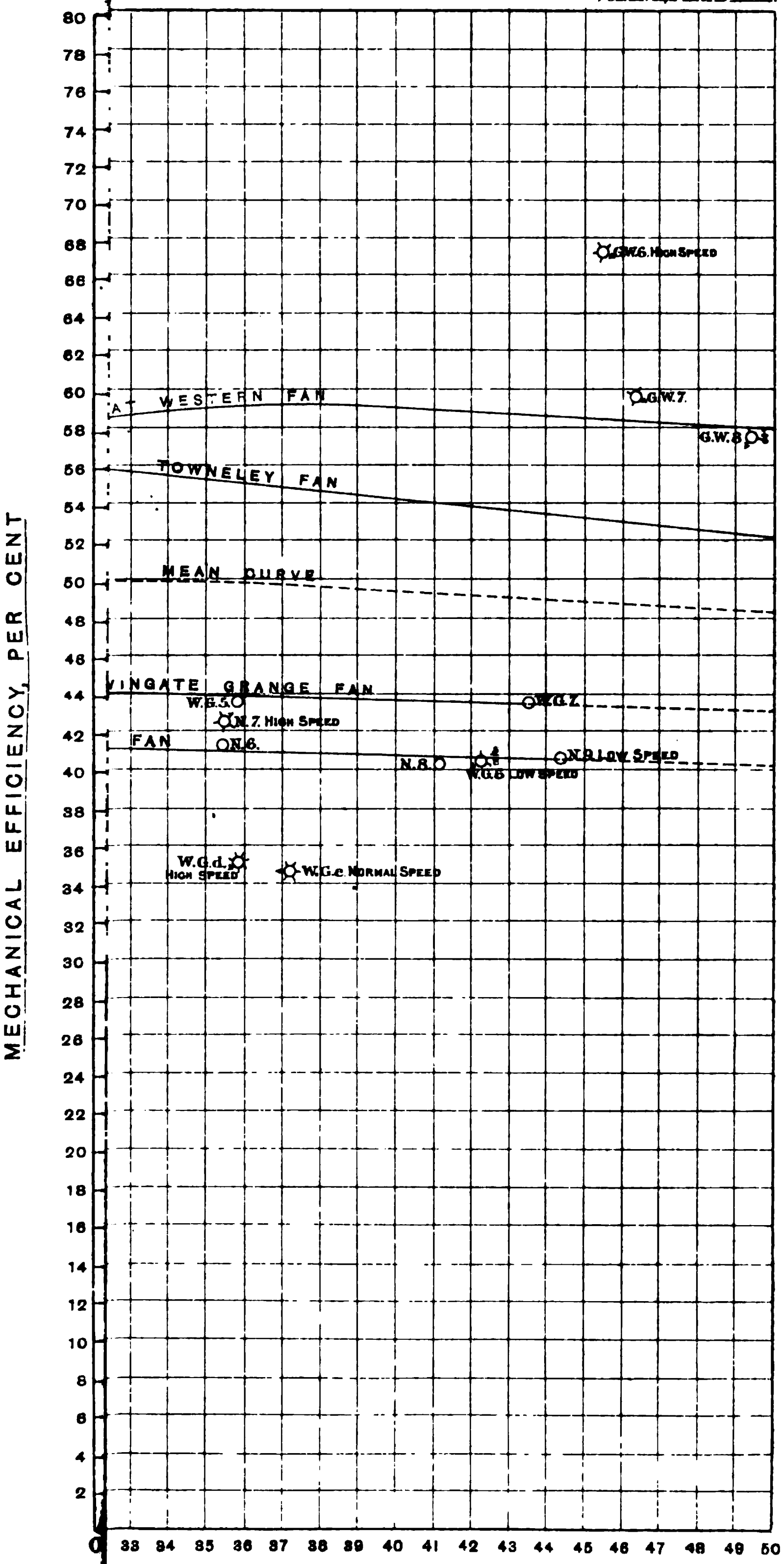
VOL XLVIII, PLATE XVII.

The Insti tutors." Vol. XVII. Plate XXV.

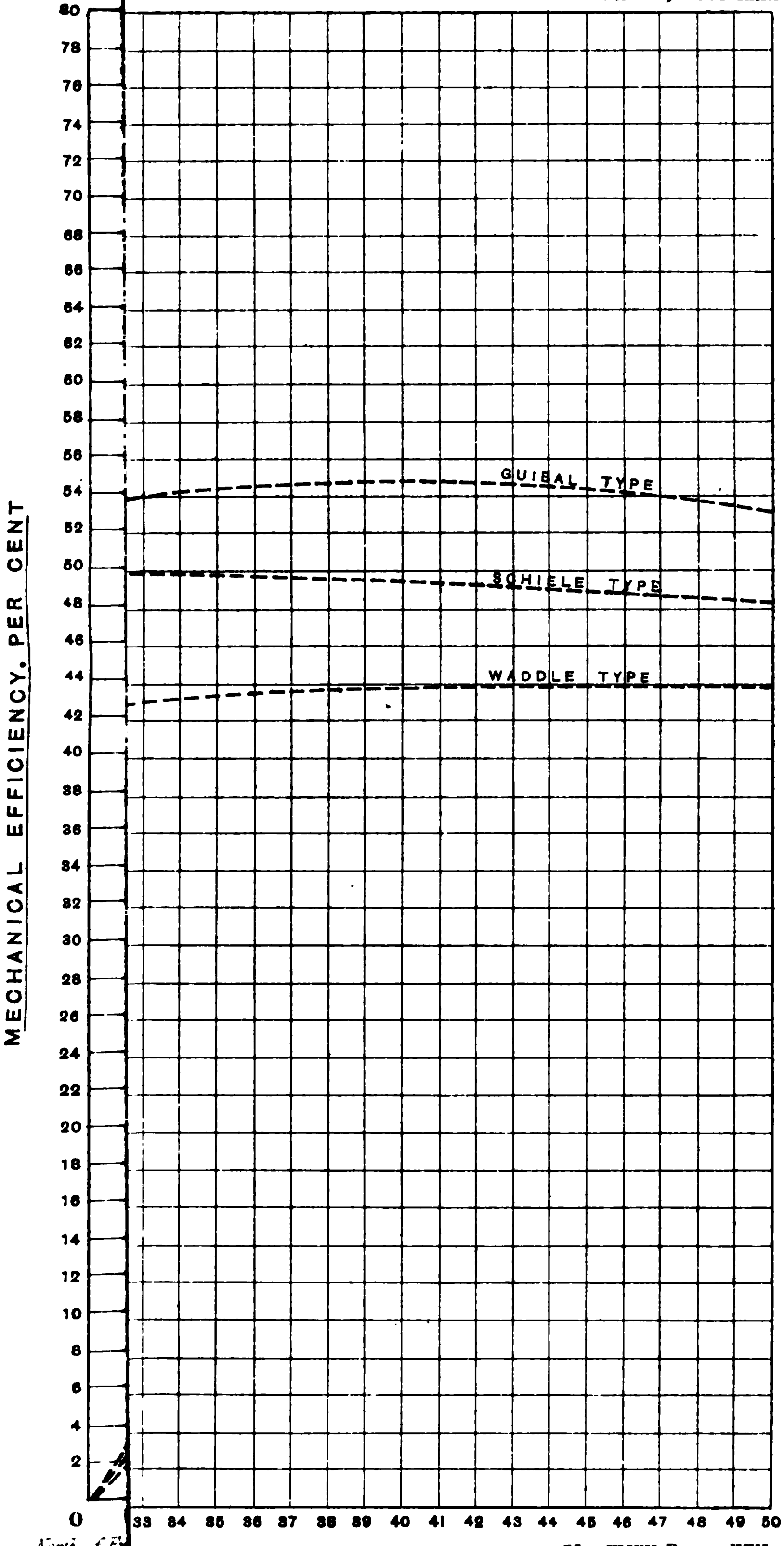


North of Vol. XLVIII. Plate XIX.


VOLUME OF AIR, CUBIC FEET PER MINUTE.
200,000
190,000
180,000
170,000
160,000
150,000
140,000
130,000
120,000
110,000
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
B
GUIBAL TYPE
WADDLE TYPE
SCHIELE TYPE
2
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50


MECHANICAL EFFICIENCY, PER CENT
80
78
76
74
72
70
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
G.W.6. High Speed
A T WESTERN FAN
G.W.7.
G.W.8
TOWNELEY FAN
MEAN CURVE
VINGATE GRANGE FAN
W.G.5
N.7. High Speed
W.G.7.
FAN
N.6.
N.8.
W.G.6 Low Speed
N.9 Low Speed
W.G.d.
High Speed
W.G.e. Normal Speed

N. rtr. of T.


MECHANICAL EFFICIENCY, PER CENT
80
78
76
74
72
70
68
66
64
62
60
58
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52
50
48
46
44
42
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
33
34
35
36
37
38
39
40
41
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45
46
47
48
49
50
GUIBAL TYPE
SCHIELE TYPE
WADDLE TYPE

The PRESIDENT (Mr. J. A. Longden) said that the members had been waiting for this paper for some time, but its publication had been delayed, owing to circumstances over which the Committee had no control. There were difficulties with regard to testing the efficiencies of fans, even when situated in the same mine. It was not usual to erect two fans at the same time, one was erected first, and when that was becoming defective another fan was erected, probably of a different type, and the probability was that the older fan would be the less efficient. Mr. W. Cochrane, who was the first to adopt the Guibal fan in the North of England, used to say that the efficiency of the Guibal fan was considerably greater owing to the use of the expanding chimney, but if they were going to put up a costly structure, such as was necessary for the Guibal fan, they must take that into account in reckoning the efficiency as compared with the additional cost in the first instance. He was surprised at the small amount of natural ventilation which the Committee had credited. Some years ago, the natural ventilation of a small colliery, after the pit had been standing, was found to be 30,000 cubic feet per minute with longwall workings, and 30,000 cubic feet was much higher than the average found by the Committee. Another point which struck him was that when they erected a fan in the first instance they put it down for what they expected would be the ultimate requirements of the mine, and possibly twice as large as they required at first. The Committee had found out that a certain fan on a certain mine would give a certain efficiency, and if they altered the conditions the efficiency would be considerably increased or reduced. It was satisfactory to find that the three fans tested were so little different in their efficiency, which he supposed was about 55 per cent.

Mr. ARNOLD LUPTON (Leeds) said that the members wanted to know (1) which fan would, if so designed as to deal with the air in the most economical way, give the best result; and (2) what particular installation of boiler, steam-engine and fan would give the most economical result; they were two distinct questions, and the Committee had answered neither. It gave them a mixture. It selected the steam-engine and fan, and left out the boiler. One fan and steam-engine did not always give the same efficiency, because the percentage of friction varied in proportion to the amount of work done. The friction of a fan varied, roughly speaking, in proportion to its weight, and in a large fan, say, 8 times the weight of a small one, they had approximately 8 times the friction, because the larger diameter of the shaft carrying the large fan would compensate for the greater number of revolutions by the shaft carrying the small fan, assuming that both fans ran at the same periphery-speed. To secure economy of fuel, the design of the steam-engine and boiler was of twice as much importance as the design of the fan.

Mr. C. C. **Leach** (Seghill) suggested that the difference in the efficiency of the fan was due to the friction of the air passing through the fan, consequently a small fan could not be as efficient as a larger one. It appeared to him that there was no material difference between the efficiency of one fan and another, but there was in the chosen engine.

Mr. **Hugh Waddle** (Llanelly) wrote that the *Report of the Committee on Mechanical Ventilators* was somewhat misleading, as mining engineers might think that the Waddle fans tested were of modern make. In reality they were of quite obsolete construction; but even these, however, compared favourably with other fans. One of the first of the improved Waddle fans, that at Craghead colliery, was tested by Mr. M. Walton Brown, and the mean result of a number of experiments showed an efficiency of over 65 per cent.† It was very important that attention should be given to the design of fan-engines so as to secure economy of steam-consumption; but due regard must also be paid to the fact that a fan-engine had to run continuously night and day for long periods without a stoppage, and that even a slight temporary break-down might entail removing all the workmen out of the pit. It was, therefore, a serious mistake to add unduly to the number of working parts by a complicated system of valve-gear, or in other ways, with the prospect of only a slight reduction in the steam-consumption, as any slight advantage that might be gained might be more than lost by a single break-down. He did not agree with the idea that the efficiency of a fan was a minor matter. Thus, a fan might give a useful effect of only 30 per cent. while another gave 60 per cent.; but if the work in the air was the same for both fans, one would use twice as much coal as the other. In the endeavour to obtain economy of consumption, compound engines were sometimes adopted under wholly unsuitable conditions: for instance, it was not unusual to see a huge compound engine, working non-condensing with about 80 pounds of steam-pressure, driving a fan which gave a ridiculously small volume as compared with the power of the engine, and such conditions meant that a great waste of fuel was taking place. When, however, the boiler-pressure was sufficiently high, and the engine better proportioned to the work to be done in the air, he had found that a compound engine might lead to a considerable saving of fuel even when there was not a sufficient supply of condensing-water.

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† *Trans. Inst. M.E.*, vol. ii., page 173.

Mr. B. Donkin (London) wrote that he was very glad to see the account of so excellent a series of experiments. He had read the details of the tests with much interest, and had much pleasure in adding a few remarks, having made many experiments on steam-engines and small centrifugal fans. It seemed a pity that more modern types of ventilating-fans had not been selected and tested. Many of those on which the experiments were made were 25 to 30 years old, and sometimes they could not be run at the required speed. It was very desirable that experiments should be made on other and more modern types; and if one or two could be tested each year this would diminish the labours of the engineers and others, who gave their valuable time to the subject.

The uniform programme of experiments drawn up by the Committee seemed a good one—100 feet per second circumferential speed was adopted as the normal velocity at the tips of the vanes; the equivalent orifice had also been adopted as a basis of comparison on the lines laid down by Mr. D. Murgue and a committee of the Société de l'Industrie Minérale, and their experience had wisely been more or less utilized. This society had made many experiments and had given more attention to the subject up to the present than British experts. It was just such a series of experiments, based on the characteristic curves of each fan that should be undertaken by The Institution of Mining Engineers, in order to enable engineers to compare the working results of well-known fans, and to facilitate their study, by accurate and independent records of facts, and to bring out the relative advantages and drawbacks of each fan.

The anemometer in such experiments was an important instrument, as it gave the speed of the air, which multiplied by the area gave the volume of the air per minute. He was rather surprised that nothing was said on so important a point as the testing of the anemometers. If they were only tested in the usual way in a circular path, these results were in excess and not correct. This question had been discussed before, and the Breslau experiments were quite conclusive on the point. Anemometer-readings should always be accepted with much caution, as they might be some 7 to 13 per cent. in excess.* This would not alter much the relative but only the absolute results of the fans. The Pitot tube was a more reliable and delicate instrument than the anemometer for air-measurements.

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* "Experiments on Centrifugal Fans," by Mr Bryan Donkin, *Minutes of Proceedings of the Institution of Civil Engineers*, vol. cxxii., page 265.

The depression or the amount of vacuum produced by each fan was, it was stated, observed by means of an ordinary water-gauge; he (Mr. Donkin) had found it difficult with such tubes to read nearer than about 0·05 inch of water, and he had employed with advantage an instrument which multiplied 10 times, so that 0·05 inch of vacuum was shown on the magnified gauge as 0·50 inch. This instrument admitted of much greater accuracy of reading, say to within 0·005 inch of water.

It was stated in the paper that for each steam-cylinder the two ends were joined by a pipe with one cock, so that one indicator was used for both ends of each cylinder. He was of opinion that this method did not give correct results, and that the right and proper way, as now acknowledged by most leading engineers, was to use no pipe, but to have an indicator screwed direct on to each end of each cylinder. Nothing was stated in the paper as to the indicated horsepower required to drive the engine alone, with the fan disconnected. This, although often difficult, should, if possible, always be ascertained, to show mining engineers that considerable power was absorbed by the engine when running empty.

The REV. G. M. CAPELL (Stony Stratford) said that, in the report of the trials of mechanical ventilators, there was one point to which very strong exception could be made, as the manometric efficiency was calculated on the water-gauge recorded at the inlet of the fan. This depression was not a real measure of the action of a fan on a mine, as the water-gauge at that point might be largely produced by the velocity of air-flow, and not to drift-pressure extending into the mine. In the case of the Guibal fan, 40 feet in diameter and 12 feet wide, at Great Western colliery, the inlet water-gauge, with 338,819 cubic feet of air passing was 1·550 inches, while the drift water-gauge was only 0·420 inch—a vast difference. He maintained that some fans did not make large differences between the static water-gauge (which was still lower than a drift water-gauge) and the inlet water-gauge. The Capell fan at Marles colliery, 12½ feet in diameter and 9 feet wide, exhausted 203,328 cubic feet of air per minute from the mine under normal conditions, and the water-gauge, about 6 feet distant from the inlet, was 9·10 inches, while the static water-gauge, taken in a deep recess in the drift-side with a coiled pipe with guarded end, was 8·35 inches. The difference between the inlet and the static water-gauge was only 0·75 inch; while the Guibal fan at the Great Western colliery showed a difference of no less than 1·13 inches in favour of the inlet water-gauge, when passing a volume of air very small in proportion to its body capacity, that of the Capell fan being 1,105 cubic feet, and that of the 40 feet Guibal fan being 17,592 cubic feet. He was of opinion that the manometric efficiency of fans should be reckoned on the static water-gauge for choice, next on the drift water-gauge, and never on the inlet water-gauge. The question of large fans versus small fans arose in the report, and Mr. Walton Brown was entirely in favour of the large Guibal fan. Capell fans, varying from 12 to 14 feet in diameter, had superseded about 60 Guibal fans, varying from 30 to 42 feet in diameter, and in many cases it had doubled and more the air produced by the existing Guibal fans, with four times their water-gauges. He thought that there must be something to be said in favour of small fans, compared with the now obsolete-type of large fans. Of recent years Capell fans had been made to pass 270,000 cubic feet of air per minute at 14 inches of water-gauge, a task which no Guibal fan could effect. It was to be regretted that no high water-gauge tests were possible in the exhaustive experiments so carefully made by the Committee.

Mr. M. Walton Brown, replying to the discussion, said that the mechanical efficiency of a fan was not a constant quantity, and varied with the orifice of the mine, from *zero* upwards. Table E* shewed that the mechanical efficiency of the Guibal fan varied from 0 when the orifice was closed, to 24·5 per cent. on an orifice of 10 square feet, 43·4 per cent. at 20 square feet, 52·7 per cent. at 30 square feet, 54·8 per cent. at 40 square feet, and fell to 53·2 per cent. for 50 square feet; and for larger orifices there was a continuing decrease in the mechanical efficiency. It was obvious, therefore, that as the airways were improved, a higher mechanical efficiency was produced by the combined engine and fan. Recently, with an expenditure of less than £1,000, the ventilation of a mine had been considerably improved, and that amount would be speedily recouped in the reduction of the coal-bill of the boilers required to drive the fan. He (Mr. Brown) wished specially to point out that engineers should not say that a fan had a mechanical efficiency of 55 per cent., but rather that on an orifice of 40 square feet, the mechanical efficiency was 55 per cent.; it was evident, therefore, that a fan with a mechanical efficiency of, say, 25 per cent., should not be condemned—if the mine had a resistance equivalent to an orifice of 10 square feet. The efficiency of the fan alone, shown by its manometric efficiency, which was also the measure of the resistance of the fan to the passage of air, was recorded in Table I*., which showed that the enclosed Guibal fan had a manometric efficiency of 0·636, the enclosed Schiele fan of 0·502, and the open-running fan only 0·464, clearly proving the superiority of the enclosed fan over any other type. He noted that Mr. Arnold Lupton agreed with him (Mr. Brown) that the choice of an efficient engine very materially affected the mechanical efficiency of a ventilating-fan, an efficient fan being practically valueless when driven by an inefficient engine.

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* Page 508.

The volume of natural ventilation was 60,605 cubic feet per minute at National colliery, and 68,426 cubic feet per minute at Wingate Grange colliery, the former being measured in June and the latter in February.

British engineers had made numerous experiments upon ventilating-fans, and the North of England Institute of Mining and Mechanical Engineers had published many records, including those of a Committee which had reported upon the subject.†

He did not know the name of the water-gauge to which Mr. B. Donkin had referred, but he could commend the König gauge as a suitable apparatus : he had used it in his experiments, it had been used by Mr. T. L. Elwen in some minute observations,‡ and he had described the instrument.§

The difference, 1·13 inches, between the No. I. or inlet water gauge, 1·55 inches, and the No. II. or drift water-gauge, 0·42 inch, in an experiment upon the Guibal fan at the Great Western colliery, arose from the opening of doors, on the surface, closely adjacent to the No. II water-gauge.¶

The Committee were desirous of testing any efficient fan after a consideration of the results of any previous experiments.

The PRESIDENT (Mr. J. A. Longden) proposed a hearty vote of thanks to the Mechanical Ventilators Committee for the interesting and valuable report which had been drafted by their honorary secretary, Mr. M. Walton Brown, who must have spent an enormous amount of time in collating the numerous experiments.

Mr. ARNOLD LUPTON, in seconding the vote of thanks, said that he always regarded the fan question as one upon which there might be *bonâ fide* discussion. He recognized the vast amount of labour required to produce the results set forth in the lengthy and exhaustive report of the experiments, and the members were under a debt of gratitude to the Committee, and to the engineers who had devoted so much time and talent to the service of their fellow-engineers. He had the utmost pleasure in seconding the vote of thanks to them, and to Mr. M. Walton Brown for the great amount of labour involved and talent displayed in enunciating the results of the experiments so clearly in his exhaustive report.

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* Page 516.

† *Trans.* 1881, vol. xxx., page 273.

‡ "Resistances of Air-currents in Mines," *Trans. Inst. M.E.*, 1895, vol. x., page 62.

§ "König Differential Gauge," *Ibid.*, 1891, vol. iii., page 452.

¶ Plate XV., Fig. 5.

The vote of thanks was cordially adopted.

The PRESIDENT proposed that the thanks of the members of The Institution of Mining Engineers be accorded to the Geological Society of London for the use of their rooms; and to the owners of the Hyde Park Court Mansions, Messrs. C. Isler and Co., Messrs. Johnson and Phillips, and Beeby's Brick Company, Limited, for having opened their works to the inspection of the members; to the Incorporated London Chamber of Mines, and their secretary (Mr. E. Jerome Dyer), for facilities accorded in connexion with their visit to the Mining Section of the Greater Britain Exhibition at Earl's Court; to Messrs. Edward Chester and Company, Limited, who were to entertain the members that evening; and to the Great Northern and other railway companies for valuable travelling facilities.

Mr. ARTHUR SOPWITH said that owners of works often put themselves to a great deal of trouble in preparing for the reception of visitors, and he had great pleasure in seconding the vote of thanks.

The vote of thanks was carried with acclamation.

Mr. JAMES BARROWMAN moved that the thanks of the members be given to the President for his services in the chair.

Mr. JOHN ASHWORTH seconded the motion, which was cordially approved.

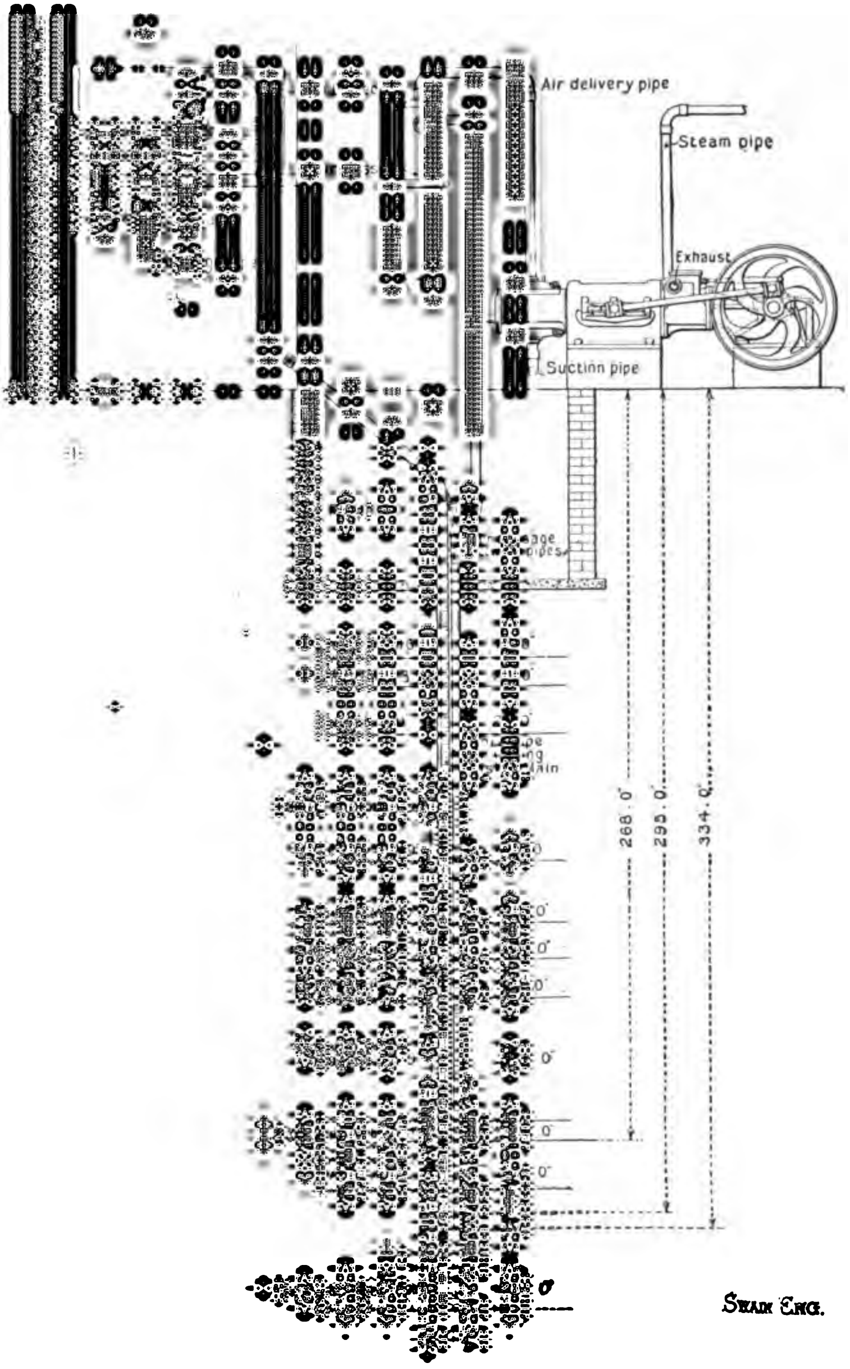
The meeting then concluded.

The following notes record some of the features of interest seen by visitors to the Greater Britain Exhibition at Earl's Court, works, etc., which were, by kind permission of owners, open for inspection during the course of the London Meeting on May 25th, 26th and 27th, 1899 :—

BACON AIR-LIFT PUMP.

At Hyde Park Court Mansions, Knightsbridge, London, a well 10 inches in internal diameter has been bored through London Clay and various sand-beds 284 feet thick, into Chalk-with-flints 166 feet thick, the total depth of the well being 450 feet. The upper portion of the boring is lined with a steel-tube 10 inches in internal diameter, and this extends 11 feet into the Chalk. The water-level stands at 105 feet from the surface. It is stated that, even when pumping at the rate of 8,000 gallons an hour is being carried on, the water-level is unaffected.

The Bacon air-lift pump is practically unknown in this country, as there is only one other installation at work. It is extensively used in Germany and in the United States of America, where it is employed in pumping the water-supply of towns. At Hyde Park Court, inside the lining tube, there are two pipes, one inside the other, having diameters of 3 and 5 inches respectively (Fig. 1). The process of pumping is as follows:—By means of a compressor, air is forced down the annular space formed between the 5 and 3 inches pipes. The pipes are arranged so that they are both below the water-level, and the air-pressure causes the water to rise in the central or 3 inches pipe, and this continues until the water-level in the 5 inches pipe has descended to the level of the bottom of this tube. The air then escapes up this tube, taking the water with it and lifting it to the desired height. The size of the central pipe, and the depth to which it must be taken are points which have to be arranged to suit each particular case. It must be, for instance, of the right diameter, having regard to the quantity of water to be raised, and the amount of submergence found necessary determines the air-pressure required. If this pipe be too small, the quantity of water lifted will fall off, and if too large, air will be lost. The inner pipe must also be placed below the level to which the water falls when being pumped. The machinery at Hyde Park Court Mansions consists of an air-compressor, having a steam-cylinder 10 inches in diameter and 12 inches stroke. With a steam-pressure of 60 pounds per square inch and when running at 90 revolutions per minute, this


Air delivery pipe
Steam pipe
Exhaust
Suction pipe
pipes
268.0'
295.0'
334.0'
Swain Eng.

compressor is capable of delivering air into the 5 inches tube at a pressure of 70 pounds per square inch, and of raising 7,600 gallons of water an hour to a height of about 120 feet. At Hyde Park Court, the water is delivered into a receiving-tank, whence it flows by gravitation into a tank situated in another part of the building. When pumping begins, the water is ejected with some force from the rising-main, which is surrounded by a baffle-plate. Very shortly, however, the violence of the discharge abates, and though slight pulsations are noticed, the delivery becomes practically continuous and regular.

The above work was carried out by Messrs. C. Isler and Co., Southwark.

MESSRS. JOHNSON & PHILLIPS, CHARLTON JUNCTION.

The members saw the Nodon-Bretonneau electric process for the seasoning and preservation of timber. *

GREATER BRITAIN EXHIBITION, EARL'S COURT.

The members visited the Mining Section, under the control and management of the Incorporated London Chamber of Mines, comprising exhibits of gold in the shape of nuggets, bullion and ore; copper, tin and other ores; diamonds, turquoise, opal and other precious stones, etc., from Queensland, Victoria and the Witwatersrand, and British South Africa. Various appliances for extracting minerals from ores were seen in operation in the mining machinery courts, including exhibits by the British South Africa Company, the governments of Queensland and Victoria, and the Witwatersrand mining companies.

THE QUEENSLAND COURT, GREATER BRITAIN EXHIBITION.

By Chas. S. Rutlidge, F.R.G.S., F.R.C.I.

Among the notable exhibits in the Mining Section of the Greater Britain Exhibition were the ores, specimen-stone, gems, and retorted gold of the colony of Queensland; the actual retorted gold on view and within arm's-length of the visitor being valued at over £31,528. Each of the 68 gold-fields of Queensland, embracing

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* *Trans. Inst. M.E.*, vol. xvii., page 427.

an area of 18,638,010 acres, contributed almost without exception to the finest and the most instructive display of minerals ever presented in London by a single colony.

The principal gold-fields, in point of development, are Charters Towers, Gympie, Mount Morgan and Croydon. The relative yields of these, and the eight gold-fields next following in point of importance, were strikingly shown by twelve gilded trophies in the form of obelisks and Ionic and Corinthian columns, inscribed as follows :—(1) Charters Towers: yield of gold, 1872 to 1898, 4,399,725 ounces; value, £15,179,051. (2) Clermont: yield of gold, 1860 to 1898, 210,845 ounces; value, £716,873. (3) Coen: yield of gold, 1876 to 1898, 30,031 ounces; value, £86,339. (4) Croydon: yield of gold, 1885 to 1898, 761,064 ounces; value, £1,921,687. (5) Eidsvold: yield of gold, 1886 to 1898, 104,709 ounces; value £379,570. (6) Etheridge: yield of gold, 1880 to 1898, 601,034 ounces: value, £1,682,895. (7) Gladstone: yield of gold, 1862 to 1898, 123,919 ounces; value, £433,716. (8) Gympie: yield of gold, 1867 to 1898, 2,311,900 ounces; value, £8,091,650. (9) Hodgkinson: yield of gold, 1876 to 1898, 242,073 ounces; value, £847,255. (10) Mount Morgan, Rockhampton district: yield of gold, 1858 to 1898, 2,222,045 ounces; value, £8,888,180. (11) Palmer: yield of gold, 1873 to 1898, 1,356,370 ounces; value, £5,425,480. (12) Ravenswood: yield of gold, 1868 to 1898, 497,725 ounces; value, £1,742,037. In this connexion it might be noted that in the space of 41 years, Queensland had contributed 895 tons 13 cwts. of gold, of a value of £45,236,212 (the bulk being strikingly shown by a 30 feet wide golden replica of Temple Bar); and that the yield of gold per miner employed was greater than in any of the prominent mining countries of to-day.

The display of opals and other Queensland gems, in addition to exhibits by the Queensland Department of Mines, and private owners, included a magnificent display by Messrs. Flavelle, Roberts & Sankey, Limited, of Brisbane, the latter being worth about £13,000.

Altogether the mining exhibits, which filled a large portion of the 30,000 feet of space occupied by the Queensland Court, were worth about £70,000, embracing, in addition to those already mentioned, tin-ores from Heberton and Stanthorpe, both "lode" and "stream," while the metal itself was shown in pigs or ingots, and in the more attractive form of "drippings" from the smelting-furnaces of Irvinebank. Silver-ores from Chillagoe, Montalbion and Pikedale formed a striking exhibit, and a "thing of beauty" was contributed by the

Aldershot Smelting Works in the shape of a case of granulated fine silver. Aldershot also furnished a pile of pig-lead.

Copper was exhibited in quantities sufficient to prove that Queensland was exceptionally endowed with that metal. Chillagoe alone sent about 40 tons of varied ores, whose contents were many times the value of the ores of Rio Tinto, and most of the profitable copper-mines of the world. Chillagoe also exhibited a nugget of native copper, weighing 1½ tons. Cloncurry sent a wonderful nugget of 7 cwts., and a lump of carbonate of copper, weighing 2 tons. The latter, it might be mentioned, had been lent by the Kelvingrove Museum, Glasgow, and had had a new face put on it since its arrival in London, the Glasgow atmosphere having given it a " tone " in keeping with its surroundings. Peak Downs had a unique exhibit in the shape of an iron door which has been converted into a massive slab of copper. The door closed one of the levels which had been standing for years under water, containing copper in solution, and had been discovered in its transmuted form in the course of draining the mine.

Queensland could—as some day it will—supply the world with iron, but as at present it does not pay to carry the ore to the market, although of almost the full theoretical or mineralogical purity, iron-ores were sparsely represented. Some huge crystallised specimens, however, from the Chillagoe district could not fail to excite the envy of curators of museums. Wolfram, the tungstate of iron, was shown by several districts. Pine Mountain and the Burnett district sent chromate of iron.

Among the other metallic ores may be mentioned auriferous bismuth from Mount Biggenden and Mount Shamrock, cobaltiferous manganese from Black Snake, antimony from Neerdie and Northcote, and cinnabar from Kilkivan.

In connection with the latter, and to point out that Queensland is capable of producing quicksilver, also perhaps because the usual water fountain was felt to have become "played out," a quicksilver fountain, specially designed by Mr. Charles Bright, F.R.S.E., was erected in the centre of the hall, the fountain and the electro-motive machinery being a source of attraction to visitors.

The Industrial and Agricultural Section of the Queensland Court occupied 10,000 feet of space at one end of the hall. The most varied exhibits of tinned meats, tinned turtle, preserved fruits, hay, fancy woods, wine, natural mineral water, rum, coffee, hides, wool, sugar, tobacco, wheat, arrowroot, chicory, pottery, pearl-shell, etc., were illustrative of some of the leading industries of Queensland.

[illegible] D-ORE CRUSHING- [illegible] HIBITION.

[illegible] lon Chamber of Mines [illegible] ntative) arranged with [illegible] stall a crushing-plant. [illegible] tery ; the stamps being [illegible] er minute.

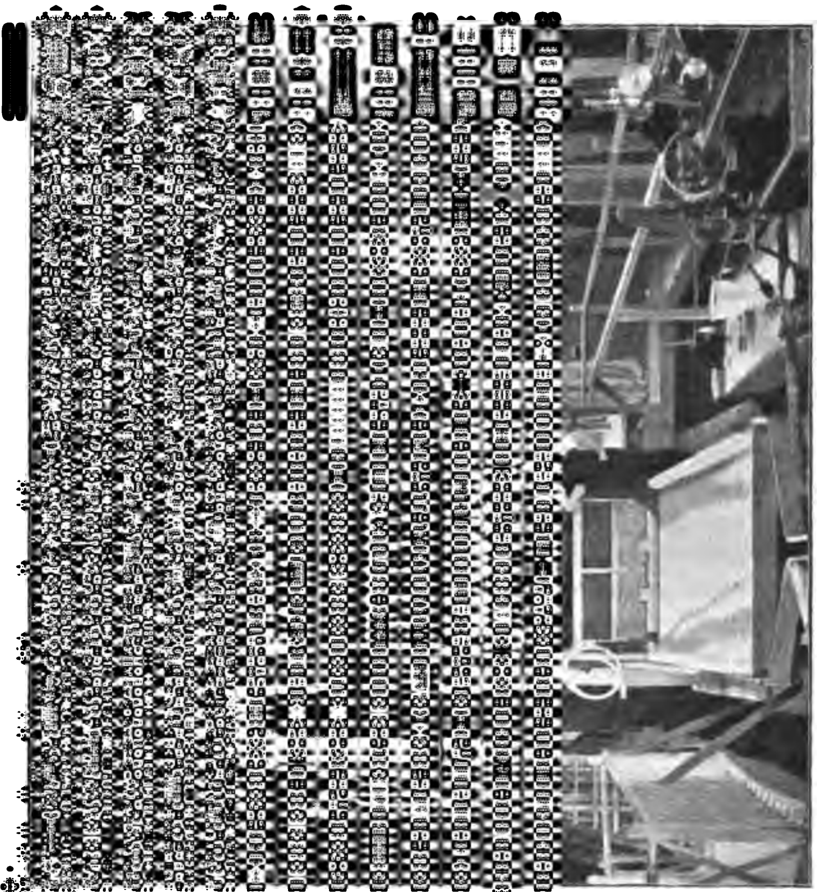

FIG. 2.—GOLD-ORE CRUSHING-PLANT.

[illegible] ize (2 inches cube), is [illegible] own, at the back of the [illegible] to the ore-feeder, which feeds it automatically into the battery or mortar-box. This feeder is worked by a bumping-rod which comes into operation, as the ore becomes crushed in the mortar-box, in the following manner. As soon as the mortar-box requires more ore, the end of the rod is struck by a tappet fixed on the stem, and until sufficient ore has been fed in, a continuous striking of the rod takes place. The feeder stops working as soon as the mortar-box has received sufficient ore.

The stamps working in the mortar-box are lifted by means of cams which are fixed on the cam-shaft, being fitted with steel-shoes, which strike upon dies of the same metal. As these stamps drop, the ore is reduced to a pulp with water, and the gold is liberated. The coarser portion of the precious metal which comes in contact with the quicksilver in the mortar-box is caught by the inside plates and amalgamated with quicksilver; and as the ore is reduced to a pulp of the proper size, it passes through the sieving and runs over the outside copper-plate, the gold that has not been caught inside the box attaches itself to this outside copper-plate, which has been previously electro-silvered and amalgamated with quicksilver.

The means of recovering the gold are as under. The gold is caught in the form of amalgam, *i.e.*, a mixture of gold and quicksilver. This amalgam is scraped off the plates from time to time, squeezed through a chamois-leather or close cloth, and then retorted. The quicksilver being driven off by distillation, there is left behind a spongy gold, which is then cut up and melted into ingots ready for sending to the mint.

The ore, after having been crushed and passed over the amalgamated copper-plates, is called "tailings." These tailings usually contain a considerable proportion of gold which is coated, or will not readily amalgamate. They are then either concentrated, or run into vats and treated with potassium-cyanide solution. The gold is there dissolved as an auro-potassium cyanide, which is soluble; and the gold solution is then pumped away from the tailings and passed over zinc shavings (not shown in this plant). The deposited gold is pressed, dried, and melted into bars.

The mortar-box in which the crushing takes place is lined with steel plates which are removable, and consequently the mortar itself undergoes very little wear, especially as it is also fitted with a false-bottom.

When it is required to stop the working of the machinery, the stamps are taken up on props or "fingers," and the tightener on the left-hand side of the battery is released, and throws the gear out of operation.

Of course in an exhibit of this kind, it was impossible to erect the plant in the same way as it would be put up at the mine; and, usually, the gas-engine which drives the machinery would be replaced by a steam-engine of the Corliss type.

In the building where this plant was erected, Messrs. Edward Chester and Co., Limited, had a large diagram showing the entire process of gold-extraction. This showed that after the tailings leave the table they are mostly elevated by a bicycle tailings-wheel, and after being elevated to the required height are run over concentrators; or they are passed through a *spitzluten*, and afterwards through a *spitzkasten*, which separate the heavier sands or concentrates. The remaining tailings are then run into tanks and treated by cyanide, and the gold present is dissolved out as auro-potassium cyanide, and deposited on zinc, either in the ordinary way by the use of zinc shavings or electrolytically.

The machinery as shown in Fig. 2 is capable of dealing with about 5 tons of ore per stamp, or 25 tons per day.

BEEBY'S BRICK COMPANY, LIMITED, BRICKWORKS, YAXLEY, NEAR PETERBOROUGH.

The first sod of the above works was cut on February 25th, 1897. They are situated on the western side of the Great Northern Railway Company's main line, about 4 miles south of Peterborough and ½ mile north of Yaxley station. The works comprize 4 Hoffmann kilns of 18 chambers each, their chimney-shafts being 160 feet high, together with the necessary engine, boiler and machine-houses. The compound engine has cylinders 23½ inches and 37 inches in diameter by 4½ feet stroke; but at present the high pressure cylinder only is being used.

The bricks are manufactured on the semi-dry principle. There are 4 grinding-pans, 8 single-mould, 2 double-mould and 1 four-mould presses, capable of turning out about 8,000 bricks per hour.

The clay is known as the Oxford Clay or Knotts, and is about 55 feet in depth, covered by about 8 feet of earth, which has to be removed. The clay is barred down into trucks, which are drawn up into the machine-houses; it is then put through grinding-pans which have perforated bottoms. By this process, the clay is reduced to a powder, and is taken by elevators into the hoppers, and from thence passes through the presses, and then the bricks are ready for burning. The exhaust-steam of the engine is used for drying (on cast-iron plates) any clay that is too wet for grinding.

The loading accommodation is conveniently arranged by three sidings (which are connected with the main railway line) running between the kilns, forming a dock or loading-stage, thus saving as far as possible manual labour.

The whole of the works are lighted by electricity, about 100 incandescent-lamps, from 16 to 50 candle-power, and 4 arc-lamps being used. A lamp socket is built into the wall of each chamber-wicket, at which a connexion is made to light the interior, when necessary for setting and drawing the bricks. The dynamo is driven by a separate engine.

NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

EXCURSION MEETING,
MAY 31ST, 1899.

CRESWELL COLLIERY.

Creswell colliery, situated 4 miles east of Bolsover colliery, is sunk to the Top Hard or Barnsley bed of coal, which averages 5 feet 8 inches in thickness.

The upcast and downcast shafts are each 18 feet in diameter, and 1,335 feet deep. There are 375 feet of cast-iron tubbing in each shaft.

The dip of the seam is about 1 in 25 to the east. The stalls are 132 feet in length, and the gateroads are cut off by cross-gateroads about every 360 feet, the coal being worked entirely on the longwall system.

Coal is drawn at the downcast shaft, as the colliery is not yet fully developed: the present output is about 2,400 tons daily.

The mine is ventilated by a Walker fan, 20 feet in diameter and 6 feet wide, with double inlets, and is capable of producing 200,000 cubic feet of air per minute, under 3 inches of water-gauge, at 180 revolutions per minute.

There are 10 Lancashire boilers, 30 feet long by 8 feet in diameter, working at a pressure of 100 pounds to the square inch, fitted with Hodgkinson coking-stokers: the hoppers of these stokers being supplied with slack from the screens. A creeper carries away the ashes from the boilers.

The winding-engine at the upcast shaft has two cylinders, each 40 inches in diameter by 7 feet stroke, and the drum has a diameter varying from 21 feet to 23 feet. The cages at this shaft have two decks, with three tubs on each deck, averaging 12 cwts. of coal in each.

The coal is passed through mechanical tipplers on to jigging-screens, which separate the large from the small coal, and the large coal passes on to belts where it is cleaned and loaded from the ends of the belts into trucks. The small coal is raised by an inclined belt on to jigging-screens, which separate it into various qualities of cobbles, nuts and slack, all of which are loaded into trucks from the belt-ends. There is a device at the end of each belt for preventing breakage of the coal through falling into the trucks.

The winding-engine at the upcast shaft has two cylinders, each 25 inches in diameter by 4½ feet stroke, and a drum 12 feet in diameter. It is intended eventually to wind 700 tons of coal per day at this shaft. It is fitted with single-deck cages, loaded with three tubs. The decks of the cages are loaded and emptied simultaneously both at the pit-top and the pit-bottom.

The sidings are extensive, and no locomotive is required. There are connexions with the Midland and the Lincolnshire and Derbyshire railways.

An extensive colliery-village is being built, and will eventually consist of 280 cottages, a number of houses for officials, co-operative stores and club-house. New schools are being built by the colliery company and the Duke of Portland jointly.

NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD AT THE NORTH STAFFORD HOTEL, STOKE-UPON-TRENT, JULY 24TH, 1899.

MR. J. C. CADMAN, PRESIDENT, IN THE CHAIR.

The following gentleman, having been previously nominated, was elected:—

ASSOCIATE—

Mr. JOSEPH BATEMAN, Under-Manager, Godley Brook, Dilhorne, Blythe Bridge.

DISCUSSION ON MR. BENAIAH PARKER'S "NOTES ON COAL-CUTTING MACHINERY IN USE AT FOXFIELD COLLIERY."*

Mr. B. PARKER, replying to questions, said that 15 to 16 horsepower were required to work one machine. The motor, with an output of 70 ampères at 450 volts, had sufficient power to work two machines, leaving an ample margin. The current varies from 25 to 35 ampères when running the machine. Persons had received shocks from the conductors, and owing to leakage from the machine, the current had been communicated to the rails, but no one had sustained personal injury. The leakage appeared to be caused by oscillation of the machine when at work. The oscillation had a tendency to wear the armour of the cable and thus cut the current. The main cable was fixed in the shaft without any covering box or pipe. They had worked the coal-cutting machine in 6 inches of water, and there was then no greater liability to leakage.

Mr. A. M. HENSHAW asked whether the coal-cutting machine had been worked under such difficulties as that of coal being so fast to the roof, or in so solid a condition as not to come down without blasting after holing; as in his experience, if the holing was limited to 4 feet in depth some time must elapse before the coal would fall. In some cases it would be necessary to hole to a depth of 5 feet, so as to avoid blasting.

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* *Trans. Inst. M.E.*, 1899, vol. xvii., page 238.

Mr. B. **Parker** replied that the Hurd coal-cutting machine could hole to a depth of 5 feet if the bar was made of suitable length. But difficulty ensued, as the colliers could not clear the cuttings in a given time, and the use of a longer bar became more expensive than beneficial, and at Foxfield colliery, the long face gave the coal time to fall, and save blasting. A Hurd coal-cutting machine was holing to a depth of 5 feet at Oak colliery, near Manchester.

The further discussion was adjourned.

Mr. W. Freakley read the following "Supplementary Notes on the Application of Condensers to Winding-engines" :—

SUPPLEMENTARY NOTES ON THE APPLICATION OF CONDENSERS TO WINDING-ENGINES.

BY WILLIAM FREAKLEY.

In his paper* he alluded to several types of condensers, and he would now describe an arrangement which, in his opinion, would be very suitable for application to winding-engines. Its main points were its extreme simplicity, high efficiency, small cost of construction and erection, and trifling cost of maintenance.

This arrangement consists (Figs. 1 and 2, Plate XXXII.) of a main condenser, *A*, to which the exhaust-pipes from the winding-engine are attached by means of branch-pipe, *B*. The injection-water is introduced by a branch-pipe, *C*. The jet impinges on a block, *D*, which causes the water to spray over the whole of the condensing space and condense the steam.

The main condenser, *A*, is furnished at its lower end, with one or more indiarubber valves, *E*, opening downwards and contained within a secondary chamber, *F*, which in turn is also furnished with indiarubber valves, *G*, similarly opening downwards.

The secondary chamber, *F*, is fitted with three small valves, *H*, *I* and *J*, provided for steam, water and air respectively. These valves are operated by cams carried on a revolving shaft, *K*, driven by means of a small engine, and the worm-and-wheel gearing, *M*. The steam-valve, *H*, is supplied with steam at a low pressure from a reducing valve. The water-valve, *I*, is supplied with water from an overhead tank, or from a suitable pump ; and the air-valve, *J*, is open to the atmosphere.

The working and action of the condenser just described is as follows :—

The small engine is put in motion causing the cam-shaft, *K*, to revolve ; then, by means of a revolving cam, the steam-valve, *H*, is raised admitting a jet of steam into the chamber, *F*, and blowing out the air. The steam-valve, *H*, is then closed and the water-valve, *I*, is opened by its cam, the water-jet instantly condenses the steam and forms a vacuum in the upper and lower condensers. The main injection-water jet, *C*, then plays into the main condenser, *A*, and condenses the exhaust steam coming from the winding-engine through the branch-pipe, *B*.

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* *Trans. Inst. M.E.*, 1899, vol. xvii., page 242.

The arrangement of the block, *D*, causes thorough admixture of the steam and water, resulting in a high vacuum with a minimum consumption of condensing water ; and whilst the water of condensation is accumulating in the upper condenser, *A*, the air-valve, *J*, is, by means of its revolving cam, opened, admitting air into the chamber, *F*, destroying the vacuum therein, and allowing the contained water to fall into the hot-well, below the valve, *G*. The steam-valve, *H*, is again opened, blowing out the air from the chamber, *F*. The steam-valve, *H*, then closes and the water-valve, *I*, opens, again forming a vacuum in the chamber, *F*, and the water which has accumulated in the main condenser, *A*, then falls into *F*. The air-valve, *I*, again destroys the vacuum, and the water falls into the hot-well as before.

By properly controlling the speed of the small driving-engine, and regulating the form and positions of the revolving cams, the arrangement will go on from day to day with little expense or attention.

The power required to operate this apparatus should not exceed ½ horsepower for the largest size of winding-engine.

In case it is desired to use a surface-condenser, it may be superposed over the above arrangement, and the action will otherwise remain the same. It is obvious that this type of condenser is capable of many modifications according to the peculiarities of each case. It must, however, be always remembered that no type of condenser can be used to advantage unless there is an adequate water-supply and suitable cooling-arrangements.

Mr. W. **Freakley** said that several condensers of this form had been used, but it had not been applied to a winding-engine. It was an arrangement which he thought would suit a winding-engine. It would require the same quantity of water as an ordinary injection-condenser used by a beam-engine or a modern horizontal engine.

Mr. W. N. **Atkinson** asked whether the upper chamber would hold the whole of the water used during the running of the winding-engine.

Mr. **Freakley** said that this condenser might be so designed. When applied to a saw-mill engine, this condenser created a vacuum as uniform as in the best constructed condenser, having an air-pump.

Mr. A. M. **Henshaw** remarked that to create a sufficient vacuum to deal with the large quantity of water required for large engines the water injected into the lower chamber would be a considerable quantity. To deal with a large quantity of water a large condenser would be required, with very quick action by means of the valves, and very quick condensing to pass a large body of water from the upper to the lower chamber. He did not believe that this condenser could become practicable by enlarging the chamber so as to hold all the water used by a winding-engine, with—say a cylinder 40 inches in diameter. Chambers would be required larger than the boilers.

Mr. T. M. **Favell** said that a condenser for a winding-engine must produce a constant steady vacuum so that they could use it at the very start of the run, or else it was of no use. The arrangement described by Mr. Freakley might be workable under certain circumstances, but he thought that it would require many modifications before being applied to a winding-engine. He thought that it might work under certain circumstances, but the larger it became the more difficult it would be to work, and he doubted whether it would work upon a winding-engine.

Mr. A. M. **Henshaw** thought that this condenser if practicable was a stride in advance of the old-fashioned condenser, with the air-pump connected with the engine itself. Theoretically it seemed good, but under conditions like those applying to winding-engines no condenser could be used under more trying conditions.

Mr. **Freakley** replied that this condenser was rather of the nature of a suggestion, and he had pointed out the possibilities of its use.

Mr. W. N. **Atkinson** moved a vote of thanks to Mr. Freakley for having brought forward the subject, which was an important one.

Mr. T. M. **Favell** seconded the resolution, which was agreed to.

Mr W. Freakley read the following " Supplementary Notes on the Compounding of Winding-engines : "—

SUPPLEMENTARY NOTES ON THE COMPOUNDING OF WINDING-ENGINES.

By WILLIAM FREAKLEY.

In a short paper* recently read by the writer, he endeavoured to show that no economy could be expected to result from the compounding of an ordinary intermittent winding-engine, and he then gave his reasons for arriving at such a conclusion.

In the course of the ensuing discussion Mr. John Heath stated that in the case of a coupled non-condensing winding-engine at the Sneyd colliery, considerable economy of steam and fuel had resulted from its conversion into a compound-condensing engine by the addition of two low-pressure cylinders and of an independent condenser.

It was also suggested that the writer should go more fully into the question, and he has accordingly prepared the accompanying diagrams, illustrative of the heat-cycle in an intermittent compound winding-engine (condensing) as contrasted with a compound continuous-running engine, also condensing. The indicator-diagrams exhibit approximately the range of temperature to which the respective cylinders are exposed, and show sufficiently why, in the writer's opinion, the compounding of an intermittent winding-engine cannot be expected to result in a saving of steam and fuel.

The indicator-diagrams Figs. 1 and 2 (Plate XXXII.) represent the action of the steam in the high and low-pressure cylinders of a modern compound continuous-running condensing engine, doing a nearly constant duty.

The initial pressure in the high-pressure cylinder is 94·7 pounds per square inch absolute, and the cut-off takes place at 0·25 of the stroke. The temperature of the steam during the period of supply is 324° Fahr., and at release 249° Fahr., while the average temperature during the return stroke is 234° Fahr. Consequently the extreme range of temperature in this cylinder is 90° Fahr. The initial pressure in the low-pressure cylinder is 20·7 pounds per square inch absolute, and the cut-off takes place at 0·30 of the stroke. The temperature of the steam during supply is 229° Fahr., and at release 177° Fahr., the temperature during the return stroke being 141·6° Fahr. The extreme range of temperature in this cylinder is therefore 88° Fahr.

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* *Trans. Inst. M.E.*, 1899, vol. xvi., page 427.

An examination of the diagrams (Figs. 1 and 2) reveals conditions favourable to economy, and in practice it is found possible to run such an engine with ordinary saturated steam, with an expenditure of 15 pounds of feed-water per indicated horsepower per hour. The cylinders are not steam-jacketed, but the surfaces are well clothed with a non-conductor. The areas of the cylinders of this engine are in the ratio of 1 and 3½, running at 400 feet of piston speed per minute.

The indicator-diagrams, Figs. 3 and 4 (Plate XXXII.), may be taken as representing what occurs in the high-pressure and low-pressure cylinders of a compound condensing winding-engine. The high-pressure cylinder has a progressive cut-off gear, the low-pressure cut-off being fixed at 0·80 of the stroke.

The absolute initial pressure in the high-pressure cylinder is 94·7 pounds per square inch, corresponding to a temperature of 324° Fahr., and is continued during the first 3 or 4 revolutions of the drum for about 0·90 of the stroke. The cut-off gear then comes into operation, cutting-off the steam earlier for each revolution. Near the end of the run the terminal pressure has fallen to near 11 pounds per square inch absolute, and the temperature of the cylinder has fallen to 197° Fahr. The extreme range of temperature in the high-pressure cylinder is therefore 127° Fahr.

The absolute initial pressure in the low-pressure cylinder is 31 pounds per square inch, corresponding to a temperature of 252° Fahr. at the commencement of the run, and is progressively reduced until at the end of the run it has fallen to 3½ pounds per square inch, or 146° Fahr. The extreme range of temperature in the low-pressure cylinder is therefore 106° Fahr.

The cylinders of the above engine are not steam-jacketed, but are well clothed with a non-conductor. The areas of the cylinders are as 1 to 2, and it is assumed that they could easily do the work before being compounded when working non-condensing, and the engine making about 30 revolutions per winding.

On referring to the diagrams (Figs. 3 and 4) and duly noting the foregoing remarks, it will be seen that the extremes of temperature in the cylinders of the winding-engine are much greater than in those of the continuous-running engine. It must be borne in mind that in the latter the cylinders are exposed to the extreme range of temperature only during each individual stroke of the piston ; in the winding-engine, however, the cylinders, pistons and passages are exposed to a gradually decreasing temperature during nearly the entire winding as well as during the onsetting and landing of the waggons ; and that during all this time the cooling influence of the condenser is acting in practically all the cylinders. The result is that at the next winding a large volume of incoming steam is condensed.

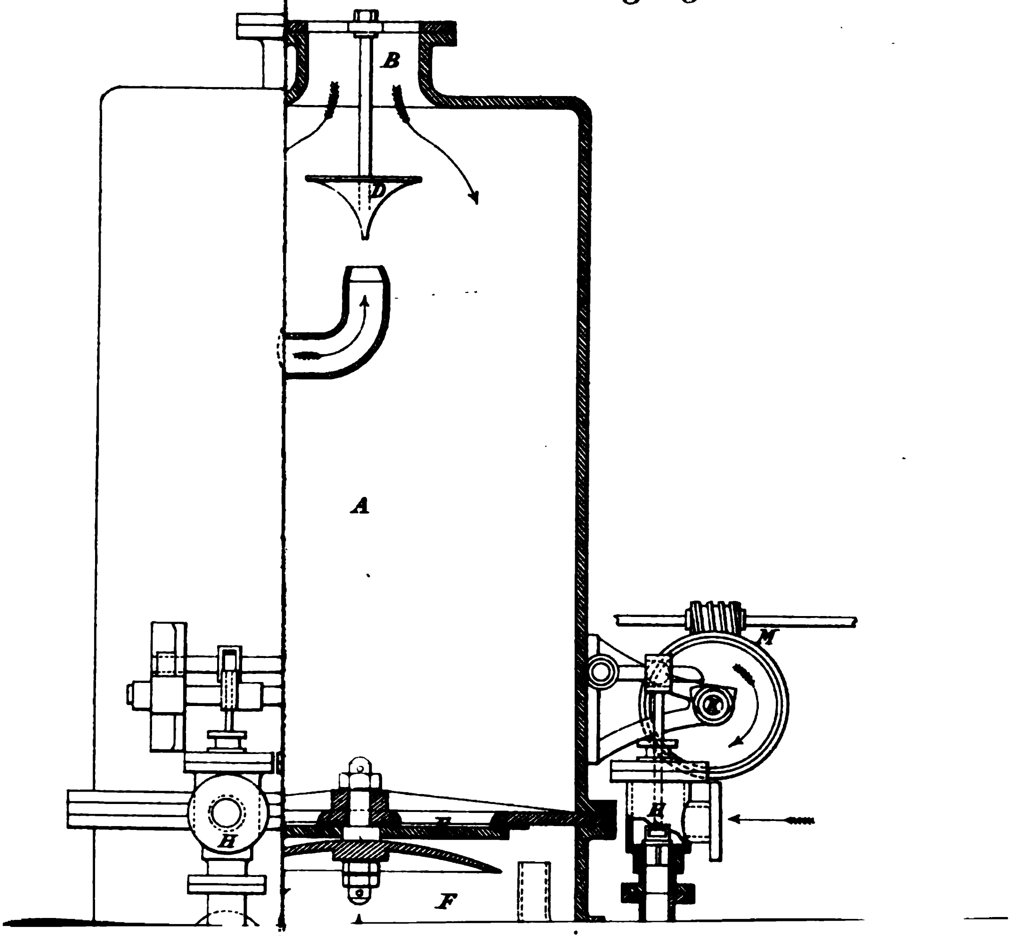
If our modern theories of steam-engine economics are sound, it must be impossible for an engine working under the above-named conditions to be economical in steam as compared with the continuous running engine. It would appear conclusive that any economy of steam over the performance of the engine before compounding must be accredited to the application of the condenser, and not to the additional cylinders. The frictional resistance also of the extra pistons, rods, etc., is further against economy. The winding-engine above described would require about 23 pounds of feed-water per horsepower per hour, which is more than would be required by a simple condensing engine.

The writer is a strong advocate of the compound engine, when used under proper conditions, but for a winding-engine he considers it in every way unsuitable. It is becoming more essential every day about collieries that winding-engines should be simplified to the fullest extent possible. And the writer believes that a well designed simple condensing engine will be used when a suitable water-supply is at hand.

Mr. John Heath said that at Sneyd colliery he was now sinking to a depth of 2,700 feet, and he advocated following on the same lines as those that he had adopted previously. The winding-engine was compound and condensing ; and he advocated the adoption of a similar winding-engine.

Mr. B. Woodworth said that he might assume that there were not many winding-engines in existence that could be compounded with advantage, as it needed a combination of circumstances to ensure its practical advantages, but in designing a new engine for heavy winding the problem might be dealt with in a fairly satisfactory manner. The main points to be observed in such a case were :—(*a*) The engine should

To illu ion of Condensers to Winding-Engines"



run as long as possible under steam during each winding. (*b*) The negative running or the time not under steam should be reduced to a minimum. And (*c*) a high pressure of steam should be used with the best arrangement of cut-off gear possible so as to obtain the greatest expansion of steam and low terminal pressure in working at and from the earliest possible point of the winding. If matters can be arranged so that the winding-engine runs under steam at a piston-speed of 250 feet per minute, occupying from 50 to 60 per cent. of the total time of each winding in doing so, and utilizes a cut-off on and from the second revolution of the winding, then we may (in the absence of other practical difficulties) adopt compounding and rely upon reaping a tolerable advantage in doing so, although it is not possible to obtain anything like such good results as can be obtained with a continuous running engine. Simultaneous hooking-on and landing with a combination of the balance-rope system of equalizing the load throughout the winding are the best means available for securing conditions *a* and *b*, and although the whole of the conditions above named are necessities for successful compounding of a winding-engine they are also extremely advantageous in their application to all winding-engines where possible.

The PRESIDENT, moved and Mr. JOHN HEATH seconded, a vote of thanks to Mr. Freakley for his supplementary paper, and the discussion was adjourned.

Mr. C. E. de Rance read the following paper on "The Genesis and Matrix of the Diamond" :—

THE GENESIS AND MATRIX OF THE DIAMOND.

By C. E. de RANCE, Assoc. Inst. C.E., F.G.S.

In this communication, the writer wishes to show how far the views of his late friend Prof. H. Carvill Lewis have been supported, or otherwise, by later communications. It is of interest to observe at the outset, that Prof. Lewis' work* was edited by the Rev. Prof. Bonney, at the request of Mrs. Carvill Lewis, in accordance with the wishes of her late husband, and that the latest communication on the subject is by Prof. Bonney, given to the Royal Society of London. The foundation of Prof. Lewis' work are papers given to the British Association for the Advancement of Science in 1886 (Birmingham) and in 1887 (Manchester).†

Previous Literature and History.—So far back as 1845 specimens of fossil plants were collected at the Sunday river (Geelhoutboom) by Dr. R. N. Rubidge, described by Prof. Morris, and afterwards exhibited at the Ipswich meeting of the British Association in 1851. He regarded them, from the preponderance of cycads, as a Secondary flora, probably of Jurassic or Triassic age.‡ These specimens found their way to the museum of the Geological Society of London, and were largely supplemented later by Dr. Rubidge and Dr. Atherstone, and supported the views taken by the late Prof. Morris. These Jurassic strata were ably described by Dr. W. G. Atherstone in a lecture on the geology of Uitenhage,§ who named them the "Uitenhage Series," and gave comparative sections seen at (1) Zwartkop river, (2) Sunday river, and (3) Bushman river. In No. 1, saliferous shales alternate with ferruginous sandstones, and the base is his Zwartkop Sandstone. In Nos. 2 and 3, the base is the Wood-bed Series, with lignite, jet, amber, and drifted and standing trees: in all three sections these deposits lie on quartzose pebbles, loosely packed in red clay, which he calls the Enon Conglomerate, and describes as unconformable on the quartzite, old slates, and schist below.

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* *Papers and Notes on the Genesis and Matrix of the Diamond*, Messrs. Longmans, Green & Co., London, 1897.

† *Report of the British Association for the Advancement of Science*, 1886, page 667; and 1887, page 720.

‡ *Ibid*, 1851, "Transactions of the Sections," page 68.

§ *Eastern Province Monthly Magazine*, vol. i., 1857, page 580.

Below the Uitenhage series, described above, is the Karoo Formation of the late Mr. Bain,* who divided it as follows, in descending order :—

A. Stormberg† Beds, named by Mr. A. Wyley, in a report addressed to the President of the Free State, on the ineffectual search for gold near this place.‡ They were also independently so named by the late Prof. Huxley.§ They contain a reptilian fauna, lignites and ferns, and they have been identified on the Natal side of the Drakensberg, by Dr. P. C. Sutherland.‖

B. The Beaufort Beds containing numerous Dicynodont remains, fossil wood and *Glossopteris.*

C. Koonap Beds, with fossil trees in hard shale.

D. (1) Upper Ecca Beds, hard blue shale, with plant-remains; (2) Dolerite, containing angular and rounded fragments of quartzite and granite, which extends across South Africa; and (3) Lower Ecca Beds, with plants and fossil wood.

Prof. Ralph Tate,¶ in describing South African fossils, points out that the *Glossopteris* of the Karoo Beds, and also other species, are identical with the plants found in the coal-formation of Eastern Australia and the plant-bearing beds of Burdwan and Nagpur in India, and regards these deposits as of Triassic age and of lacustrine origin, the flora having no affinity with the Oolitic flora which locally succeeds it.

Mr. Wyley, in *Notes of a Journey in two Directions across the Colony, made in* 1857-58,** gives a remarkable forecast of the geological sequence. He, however, refers the " Enon Conglomerate " to the New Red Sandstone, and considered the Karoo and Ecca Beds to be Carboniferous, but his description of the Trappean Breccia, of rounded and angular fragments from the smallest grain to boulders of 2 feet still stands, occurring between the Upper and Lower Karoo Shales, and he gave an early forecast of the underlying Carboniferous or Devonian Limestone and Sandstone with *Spiriferi*, underlain by more or less vertical Silurian slates and grits.

It will be noted that up to 1867, in the various papers quoted there is no reference whatever to the diamond, but in that year a large specimen being picked out of a lot of rolled pebbles gathered in the Orange river, digging then began in that, and the Vaal river. In 1870, 10,000 people had gathered on the banks of the latter, when the news came of the discovery, at a point 15 miles distant, of diamonds, yielded in dry diggings, in what was then thought to be an alluvial deposit, but since proved to be volcanic pipes. This point soon became the town of Kimberley, and in 1871 the celebrated Du Toits Pan, De Beers, Kimberley and Bultfontein mines were in active operation, in an area of 3½ miles diameter, lying on the northern end of a great plateau, known as the Upper Karoo, extending from the Cape of Good Hope to the borders of the Transvaal, varying from 2,700 to 6,000 feet above sea-level, Kimberley being about 3,900 feet. The Orange Free State mines, Koffeefontein and Jagersfontein lie respectively 30 and 60 miles to the south-east.

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* *Eastern Provincial Magazine*, 1856, page 19.

† The Stormberg mountains form part of a long range, running several miles north-eastward, and take the name of the Drakensberg, on the north-western frontier of Natal.

‡ *Bloemfontein Gazette*, January, 1856.

§ *Quarterly Journal of the Geological Society*, 1867, vol. xxiii., page 5.

‖ *Ibid.*, 1855, vol. xi., page 466. ¶ 1867, vol. xxiii. page 142.

** Quarto, Cape Town, 1859.

In 1870, in a valuable paper entitled "Some Points of South African Geology," by Mr. William Stow, of Queenstown, South Africa,* there is no reference to the occurrence of diamonds.

In the following year, Mr. G. W. Stow communicated a paper "On the Diamond-gravels of the Vaal river, South Africa," to the Geological Society,† accompanied with specimens that were exhibited and described by Prof. Rupert Jones. Mr. Stow in a letter of July 6th, 1871, to Prof. R. Jones, refers to the latter's paper "On the Diamond Fields of South Africa,"‡ as instigating him to accumulate new facts obtained by competent observers. In this paper, Prof. Rupert Jones clearly shows, quoting all published authorities, that the Karoo formation continues up the Vaal river into and beyond Transvaal, and other regions to the east, including part of Natal, and points out that in the diamond districts they have been worn down to a low level, at all events down to the Devonian strata, in which Dr. Carl Mank found Devonian fossils.

In the following year, Mr. G. W. Stow§ describing the diamond-gravels of the Vaal river,‖ Cape Colony, showed that they had an area 300 miles in length and 171 miles in width, occurring in (1) unstratified gravel with huge boulders, in ochreous matrix as at Pniel. (2) Unstratified gravel, bound together by calcareous cement, with fragments of fossil wood. (3) Stratified gravelly clays of various colours, with a few boulders, as at Hebron. (4) Pebbly drift, without boulders, as at Jagersfontein. (5) Gravelly contorted sand. The various shafts at this period did not reach more than 30 feet, and the subterranean rock beneath, the rotten-stone (of the miners), or decomposed felspathic trap (of Prof. Rupert Jones), had been reached in places and found to go down in wall-like precipices. Mr. Stow traces these gravels to be formed by denudation on a great scale over long distances, from the broken character of many of the diamonds in their rough transit with the boulders.

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* *Quarterly Journal of the Geological Society*, 1871, vol. xxvii., pages 28, 52, 497, 523 and 534. † *Ibid.*, 1872, vol. xxviii., page 3.

‡ *Geological Magazine*, 1871, page 49.

§ *Quarterly Journal of the Geological Society*, 1872, vol xxviii., page 3.

‖ The Vaal river, westward to the Atlantic Ocean, is known as the Orange (or Nu Gariep) river, it is occasionally known by the latter name where it forms the boundary between the Transvaal and the Orange Free State.

In Dr. John Shaw's paper in the same journal no reference is made to diamonds other than in the gravels, which he refers to distribution by lakes.* In the discussion on this paper, the late Prof. Tennant stated that he had seen at least 10,000 diamonds from the Cape, over 30 to 90 carats each, and Mr. Daintree pointed out that on the Burnett river, Australia, similar agate-beds occurred in which a diamond worth £80 had been found.

In 1874, Mr. Dunn† described the pipes in the shale as having been followed to a depth of 130 feet, the entangled various contents clearly showing igneous origin. The diamonds from Bultfontein were white and the stones small. At Du Toits Pan, only ½ mile off, they were generally coloured, the dealers being able to recognize the mines in which a stone had been found. The bedding of the black shale surrounding the mines is turned upwards at the edges of the pipes; they are very combustible and carbonaceous; they accidentally fired at Kimberley and smouldered for 18 months. These Karoo shales extend for 40 miles, and occasionally contain anthracite.

The late Prof. Carvell Lewis suggested that the atmosphere supplied the original source of the diamond, the carbon being derived from the shales, which derived it from the carbonic acid absorbed by the plant life. Prof. Lewis pointed out that floating reefs of true eruptive origin, as at De Beers, contain no diamonds or enclosures, whilst the adjacent diamond-bearing rock is always fragmental.‡ Prof. Lewis considered the diamond-rock special to the Kimberley district, and named it (1) "Kimberlite," a porphyritic lava. (2) Kimberlite-breccia is the same, but crushed by volcanic movements, full of broken shale and diamonds; and (3) Kimberlite-tuff, is the fragmental or tufaceous portion of the same volcanic rock.§

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* *Quarterly Journal of the Geological Society*, 1872, vol. xxviii., page 21.

† *Ibid.*, 1874, vol. xxx., page 54; also 1877, vol. xxxiii., page 879; and 1881, vol. xxxvii., page 609.

‡ *Report of the British Association for the Advancement of Science*, 1886, page 667.

§ *Ibid.*, 1887, page 720.

Prof. Bonney, in a closing note to Prof. Lewis' book, states that in 1896 the De Beers mine had reached a depth of 1,500 feet, the diamond-rock being no longer reached vertically, but by sinking shafts in the country rock and drifting out horizontally. De Beers mine at that date covered 22 acres, and Du Toits Pan mine 45 acres.

In Prof. Bonney's latest communication to the Royal Society,* he stated that the De Beers mine in 1898 was still 1,500 feet in depth, and the diamond-bearing rock for the last 300 feet was not less hard than an ordinary limestone. It was a minutely granular breccia made up of granite, diorite, and varieties of eclogite, which latter is described by Mr. Rutley † as a granular aggregate of red garnets, green omphacite and other minerals well known as occurring in Germany. In 1892, a diamond apparently enclosed in a garnet, the size of a large pea, was given to the Freiberg (Saxony) museum, as having been found in the De Beers mine. In 1897, Mr. G. Trubenbach, the London manager of the Newlands mine, found or obtained well-rounded crystalline boulders of a crystalline rock, sometimes studded round with garnets, on some of which small diamonds were covered with smaller diamonds. These specimens were brought to Great Britain, and submitted to Prof. T. G. Bonney, who found that the rock was not a concretion of the blue ground, but was a truly holocrystalline rock allied to eclogite, and on being broken open proved to contain garnets and diamonds. Prof. Bonney considered that it had been produced, like the garnets and pyroxenes, in some deep holocrystalline mass, shattered by explosions, *in situ*, by the action of steam or hot water, in the solfataric stage of a volcano, and was ejected, in shattered masses, to the surface. This view, unknown to Prof. Bonney, had already been taken by Prof. Max Bauer.‡ Prof. Bonney sums up thus :—"The diamond has been traced up to an igneous rock. The 'blue ground' is not the birthplace of it, or of the garnets, pyroxenes, olivine, and other minerals, more or less fragmental, which it incorporates." The blue ground is a true breccia and 'Kimberlite' must disappear.§

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* *Proceedings of the Royal Society*, 1899, vol. lxv., page 223.

† *Petrology*, Messrs. Longmans, London, 1879.

‡ *Edelsteinkunde*, page 225.

§ *Proceedings of the Royal Society*, 1899, vol. lxv., page 235.

APPENDICES.

I.—NOTES OF PAPERS ON THE WORKING OF MINES, METALLURGY, ETC., FROM THE TRANSACTIONS OF COLONIAL AND FOREIGN SOCIETIES AND COLONIAL AND FOREIGN PUBLICATIONS.

THE CLASSIFICATION OF ORE-DEPOSITS.

Eintheilung der Erzlagerstätten. By G. GÜRICH. *Zeitschrift für Praktische Geologie*, 1899, *pages* 173-176.

In the first place, regard must be had to the distribution of the chemical elements in the earth's crust. Now, Messrs. Rosenbusch and Vogt state that the heavy metals (iron and manganese excepted) from only 0·01 per cent. of that crust: even distribution of these would therefore presuppose excessively fine division. On the other hand, light metals are normal constituents of all the rocks in the earth's crust, and as such are universally and abundantly distributed. Bearing in mind the analogy traceable in certain chemical and physical properties of the heavy metals when compared with the light metals, it may be assumed *a priori* that the concentration of the substance of heavy metals within the earth's crust, or, in other words, the genesis of ore-deposits, is the result of identical or analogous processes in the lithosphere. The author bases his classification of the ore-deposits on these processes of concentration. He reviews the various classifications proposed by Messrs. Burat, Cotta, Naumann, Groddeck, Stelzner, and others, concluding that none of them are satisfactory, and sets forth his own, as follows—

I. Sublimation-deposits—

(*a*) Syngenetic:—The sublimation of vapours took place simultaneously with the solidification, and within the mass, of a solidifying magma, as, for example, tin-ore deposits.

(*b*) Epigenetic:—Sublimation-crusts in clefts and fissures.

(*c*) Metagenetic:—The constituents of a rock are dissolved by pneumatolysis (Prof. Bunsen) and replaced by metallic substances.

II. Magmatic or solidification-deposits—

(*a*) Syngenetic:—The ordinary form of magmatic deposits. We owe our knowledge of this type in particular to Prof. Vogt's researches.

(*b*) Epigenetic:—Only conceivable when an apophysis of a magma within the country-rock consists of a *schliere* (banded strip) rich in metals.

(*c*) Metagenetic:—Scarcely conceivable.

III. Precipitation-deposits—

(*a*) Syngenetic:—Chemical precipitation takes place simultaneously with sedimentation. The deposit originates at the same time as the enclosing rock, and "grows" in the same manner as that rock. Seams, beds, etc.

(*b*) Diagenetic:—Concentration of the ore takes place, for example, on the muddy bottom of a sheet of water: *e.g.*, reniform concretions of clay-ironstone.

(*c*) Epigenetic:—Infillings of caverns, veins, etc. No attempt is made here to classify more particularly the vein-deposits, as no sufficient genetic explanation has yet been found of the variations, metalliferous and mineralogical, that are observed. In epigenetic deposits, then, the country-rock is in existence before the ore-deposit is formed, and the ore-body grows without reference to it.

(*d*) Metagenetic:—The soluble constituents of a rock are dissolved, carried away, and in their stead the metallic substance is thrown down. The ore-deposit is of formation subsequent to the surrounding rock, but it is evolved at the expense of the latter.

IV. Separation-deposits—

(*a*) Residual deposits arise from chemical separation: a soluble rock-constituent (for example, limestone) is carried away—while a solid metallic substance (as, for example, brown iron-ore) remains unchanged behind.

(*b*) Deposits formed by mechanical separation: (1) Eluvial deposits, plateau-placers, plateau-drift; (2) Colluvial deposits, valley-drift.

The author explains that he uses the term "colluvial" in order to avoid the use of "alluvial," which, he thinks, is generally understood to imply a particular portion of the Quaternary epoch. L. L. B.

THE RECENT EARTHQUAKE IN AND AROUND ROME, ITALY.

Il Terremoto Romano del 19 *luglio* 1899. *By* PIETRO TACCHINI. *Atti della Reale Accademia dei Lincei, series* 5, 1899, *Rendiconti, vol. viii., pages* 291-296.

In Rome, this earthquake was of no less consequence than that of November 1st, 1895; but, exactly as in the previous case, the damage done was confined to the breakdown of sundry ancient or badly built walls. There was no injury to life or limb. The first tremors within the city, extremely slight, were registered by the seismographic instruments 2 or 3 seconds before 2·19 p.m. on July 19th, 1899: the most violent shock, with an intensity of 7 to 8 in the De Rossi-Forel scale, appears to have lasted about 10 seconds. Thereafter the tremors went on, diminishing in intensity, the total duration of the disturbance being at Rome not less than 6 minutes.

These tremors were practically the repercussion of the disastrous earthquake that took place in the Latian Hills, of which full details are to be published later by Dr. Cancani. Its epicentrum lay somewhere between Frascati, Grottaferrata and Marino. From these and other localities, reports concur in describing the main shock as a double one, producing first a "jumpy" motion, and after about 4 seconds an undulatory motion. Buildings in Frascati and elsewhere suffered much damage, and two arches of the Claudian Aqueduct were thrown down in the Campagna. The area over which the seismic vibrations were perceptible to the human senses was extensive, the extreme distance at which they were felt being 80 miles from the epicentrum (Island of Ventotene). Propagation eastward and westward was less marked than that in other directions: a point, indeed, usually noted with regard to earthquakes in Latium—the travel of the seismic waves being least towards the Tyrrhenian sea, west of Rome. Seismographic instruments were, of course, affected over a much wider area, reports coming in from Catania, Ischia, Siena, Florence and Padua.

The highest velocity of propagation of the quick-travelling undulations appears to have been 5·95 miles per second, and the lowest 1·66 miles per second. Slight after-shocks were felt on the same day and the next.

L. L. B.

THE EARTHQUAKE IN EMILIA, ITALY.

Il Terremoto Emiliano della notte dal 4 *al* 5 *marzo* 1898. *By* G. **AGAMENNONE.** *Atti della Reale Accademia dei Lincei, series* 5, 1899, *Rendiconti, vol. viii., pages* 321-326, *with a map and diagram in the text.*

The epicentrum of this considerable earthquake lay beneath the Apennines of Parma-Reggio, in latitude north 44 degrees 30 minutes and longitude east of Greenwich 10 degrees 20 minutes. The intensity was 8 in the De Rossi-Forel scale, and reached its maximum on the north-eastern slope of the Apennines. The area of violent shock covered about 250,000 acres, but the vibrations were perceptible to the human senses over an area 70 times as great. The duration averaged about 12 seconds, though seismographic instruments registered perturbations for a much longer period; as, for instance, 40 seconds in the case of the Parma seismograph, 15 minutes in that of the Paduan microseismograph, and well-nigh 30 minutes in the case of the Strasburg horizontal pendulum.

The author discusses at considerable length the question of velocity of propagation of the earthquake, casting doubt on the accuracy of many of the time-records supplied. He arrives, however, at the conclusion that the true velocity lies somewhere between 1·64 and 2·55 miles per second. The shock reached Prof. Milne's observatory at Shide (Isle of Wight) at 10h. 13m. 56s. p.m. on March 4th, 1898.* L. L. B.

THE EARTHQUAKE OF BALIKESRI, ASIA MINOR.

Il Terremoto di Balikesri (Asia Minor) del 14 *settembre* 1896. *By* G. **AGAMENNONE.** *Atti della Reale Accademia dei Lincei,* 1899, *series* 5, *Rendiconti, vol. viii., pages* 365-368.

Balikesri (40 degrees north latitude and 28 degrees east longitude of Greenwich) is the only known locality where this earthquake produced any damage, the intensity being 7 to 8 in the De Rossi-Forel scale. The epicentrum probably lay near there, but the seismic vibrations were felt as far as Smyrna in the south and Adrianople in the north, and the island of Mitylene in the east. The portion of the earth's surface thus affected would be included in a circle of 120 miles' radius, covering an area, say, of 48,500 square miles. Seismographic instruments in Southern Russia, Italy, and Germany were set in motion: the time-records given by them would, however, have been of little use but for the fortunate circumstance that one of the seismoscopes fitted up in the observatory at Constantinople founded by the author, about 90 miles distant from the epicentrum, gave a precise record. Combining this with the reports from Nikolaiev and Padua, respectively 435 and 807 miles farther away from the epicentrum than Constantinople, the mean velocity of the quick-travelling waves of preliminary tremors works out at about 5·17 miles per second. Similarly high velocities of propagation from Asia Minor to Europe having been registered in the case of the Aidin (1895) and Amed (1896) earthquakes, the author concludes that the facts do not altogether bear out Prof. Milne's contention that such high speeds may only be looked for when the seismic vibrations travel 5,000 to 7,000 miles away from the epicentrum, and that for distances up to 1,250 miles or so a speed of 1¼ to 2 miles per second is not exceeded.

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* Fuller details regarding this earthquake are promised for publication in the *Bollettino della Società Sismologica Italiana*, vol. v. (1899-1900).

It is true that, in the present case, the records obtained from Strasburg (1,150 miles) and from Ischia (750 miles farther away from the epicentrum than Nikolaiev) shows velocities of only 3·59 and 3·22 miles per second respectively, but the author believes that this is explicable on the supposition that the preliminary tremors which affected the nearer instruments of Nikolaiev were so enfeebled by the time they reached Ischia and Strasburg that they could not set in motion the instruments at those observatories. The Paduan microseismograph, on the other hand, is a highly sensitive instrument, as the records of many other earthquakes have shown.

All the foregoing remarks apply to the "waves of compression" or "longitudinal waves" of seismological theory. For the slower undulations, which travel through the earth's crust like the swell of the ocean, the seismograms show a maximum velocity of 1·55 miles per second. It would seem that in the case here dealt with the maximum length of a complete wave of the latter category did not exceed 9 miles or so. The shock was a double one, and took place about 21 minutes after noon on September 14th, 1896.*

L. L. B.

THE EARTHQUAKE OF LA RIOJA, ARGENTINA.

Los Temblores de la Rioja. ANON. *Boletin del Instituto Geográfico Argentino,* 1899, *vol. xx., pages* 150-161.

The capital city of the sub-Andine province of La Rioja had been already visited by a calamitous earthquake on October 17th, 1894, but the tremors described in this paper afflicted most severely the north-western portion of the province, destroying the village of Vinchina and making havoc of the mining district of Jagüe.

Premonitory shocks were felt in Rioja City on April 11th, 1889, at 4·30 p.m., and also at Tinogasta. They were of short duration and feeble at the former locality, but strong for several seconds at the latter. The next day, at 1·15 p.m., a violent shock, travelling from north to south, and lasting some 50 seconds, was felt in Rioja City, where some old walls tumbled down. It was this very shock that proved so calamitous in Vinchina and Jagüe. Tremors continued throughout the day and night till 1·10 a.m. of the 13th, and the undulations were perceptible over an immense extent of country, from La Rioja right into the provinces of Catamarca, Tucuman, Santiago del Estero, Córdoba, Rio Cuarto, etc.

The official despatches regarding Vinchina and Jagüe state that the earthquake was preceded by an awful subterranean roar: this was followed by a terrific shock, which destroyed 328 houses in both villages, Jagüe especially being reduced to a heap of ruins. Yawning fissures opened up in the earth in every direction, some of them even being circular with a central depression. At the time of the earthquake a dense cloud of dust overspread the sky, obscuring the sun, the semi-darkness adding to the terrors of the scene. Nine dead bodies were found among the ruined habitations, and a great many persons were injured.

Earth-tremors began again on April 24th, and on the 28th a specially violent shock was felt at Vinchina, causing a panic among the sorely-tried inhabitants, who were camped out in the open, in a state of dreadful misery and destitution

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* For further particulars the author refers the reader to vol. v. of the *Bollettino della Società Sismologica Italiana*, and to his catalogue of the 1896 earthquakes in the *Beiträge zur Geophysik*, vol. iv., Leipzig, 1899.

The shocks cursorily described above were registered with great exactness by the Milne seismometer, the only instrument of the kind that has yet been set up in Argentina, at the National Meteorological Office in Córdoba. Further tremors were recorded by the instrument on May 17th and June 6th, but their starting point was supposed to be much farther away than the region of the Andes. L. L. B.

SUBTERRANEAN WATERS AT BRUX, BOHEMIA.

Studien über unterirdische Wasserbewegung. By DR. FRANZ E. SUESS. *Jahrbuch der Kaiserlich-Königlichen Geologischen Reichsanstalt,* 1898, *vol.* *xlviii., pages* 425-516, *with* 3 *plates.*

The author describes exhaustively the existence of phenomena connected with underground springs in the district of Teplitz, and eruptions of water and quicksand at Brux. He points out that in the Brux district quicksand, as such, never appears to have any direct hydrostatic power, its movement being due to the erosive and transporting power of water moving under hydrostatic pressure. It is possible to remove from quicksand its contained water, which may under some circumstances amount to 40 or 50 per cent. of its volume, without the form of the former being altered, or without its power of resisting the pressure of overlying rocks being affected.

In its dry state, quicksand can be got to stand in nearly vertical walls, this property being due to the great friction between the individual grains of quartz. A very thin capillary layer of water would be sufficient to decrease this friction enormously, and it must be remembered that a mass of spheres, the surfaces of which are frictionless, would behave like a fluid. In this way, friction between the particles of quicksand practically disappears when these are soaked in water, and the quicksand then behaves as a fluid.

H. L.

GARNET-DEPOSITS OF BOHEMIA.

Die böhmischen Granatlagerstätten. By HANS OEHMICHEN. *Zeitschrift für Praktische Geologie,* 1900, *pages* 1-13, *with* 2 *figures in the text.*

An exhaustive bibliography of the subject forms the introduction to the paper, followed by a physiographical description of the hilly Cretaceous district in north-eastern Bohemia, where the garnetiferous deposits occur. It was this region, which, for many years, supplied the world's markets with garnets, but the industry has been subject to many vicissitudes, and nowadays the South African pyropes, or "Cape rubies," have asserted their victorious supremacy to such an extent that nearly all the Bohemian workings have been abandoned, except the extensive opencast workings at Podseditz The South African garnets are obtained as a bye-product in washing the famous "blue ground" of the diamond districts. Nevertheless, on the hypothesis of a possible rise in prices, there is still some prospect of a revival in the Bohemian industry, particularly if restarted on a large scale and with improved mechanical methods. The more so, too, when it is remembered that the deposits cover an area of 27 square miles, only a portion of which has been worked out, and a tenth of which may be described as exceedingly rich.

The Bohemian garnet has a fine rich dark red colour, which sometimes passes into jacinth-red, and occurs exclusively in grains of very various sizes.

It is a magnesian alumina-garnet, containing a fair proportion of lime, iron, manganese and chromium oxides. Unlike other occurrences of the mineral, clearly recognizable crystals are rarely found. The specific gravity varies between 3·69 and 3·72, the biggest grains usually found average about 0·44 gramme in weight, but some have been recorded as large as pigeons' and hens' eggs. Prices, of course, reached in 1899 a lower level than ever before.

The garnetiferous deposits are, geologically speaking, of four kinds: (1) True placers made up of Pleistocene drift, such as those of Chodolitz, Podseditz, Chrastian, Trziblitz, etc.; (2) conglomeratic deposits, such as those of Meronitz, probably of Tertiary age; (3) tufaceous breccias, as on Linhorka Hill, near Starrey, mined as the mother-rock of the garnet, and to all appearance genetically associated with the Tertiary basalt-eruptions; and (4) alluvia formed of materials derived from one or more of the foregoing.

In the placers, which consist of variegated sands and clays irregularly bestrewn with subangular fragments of gneiss (often garnetiferous), granulite, granite, garnetiferous serpentine, mica-schist, and spheroidal knobs of basalt, the precious stones which have been found besides garnet are fairly large zircons, smaller spinels, sapphires and rubies. At Dlaschkowitz, in 1869, a diamond was got for the first time, but despite very careful search, no second specimen has been obtained. This diamond, now in the Prague Museum, forms a type of its own, differing entirely from the Indian and Brazilian diamonds. Moldavites (probably of meteoric origin) have been found here and there in these placers, and the author compares the similar occurrence of meteorites in the tin-placers of Billiton.

The Meronitz conglomerate was worked 30 years ago by several shafts going down some 200 feet from the surface. About 50 people were employed, belowground in the mine and aboveground at the washing-apparatus, and something like 45 cwts. of garnets was got yearly. The conglomerate passes upward into an ashen-grey aluminous marl; this again is overlain by a dolomitic calcareous marl, often highly ferruginous; and the topmost bed of all (next to the soil-cap) is a yellow loam, which often passes into a grey clay, and contains innumerable fragments of ferruginous sandstone. The conglomerate is made up of marl, semi-opals (highly characteristic of this deposit), serpentines with a growth of garnets, granite, granulite, gneiss and mica-schist bound together by a dolomitic cement. Besides cyanite, tourmaline, zircon, etc., gypsum-crystals occur containing garnets as inclusions. The materials of this conglomerate are well rolled and smaller than the materials which appear as sub-angular fragments of the Pleistocene drifts of the placers. It is noticeable that basalt is absent, and hence the conglomerate is probably older than the Tertiary basalt-masses of the neighbourhood. It is, in fact, made up of Cretaceous material and rocks derived from a long-vanished Archæan mountain-range. Thermal waters percolating through the beds thus deposited originated various chemical processes, such as dolomitization and the formation of pyrite-nodules and gypsum-crystals. The semi-opals are the result of the action of waters charged with silica upon olivine-rock in process of alteration.

The tufaceous breccia, containing serpentine fragments with included garnets, is industrially of no great importance, but its very existence helps to account for the genesis of all the deposits. Their origin is explained as follows:—At the beginning of the Tertiary period an Archæan mountain-range existed in north-eastern Bohemia, made up of gneiss, granulite, granite, mica-schist, and a lherzolitic olivine-rock; the last-named was extraordinarily rich in garnet, and was then already altered to serpentine. Subsequently, this mountain-range was torn asunder by violent eruptions, and completely burned by volcanic outpourings. Fragments of the Archæan rocks were caught up and enveloped in the volcanic ejectamenta, and the screes, detritus-fans, etc., resulting from the previous erosion of the Archæan massif, suffered the same fate. Then the tufaceous rocks, perhaps through renewed eruptive agencies, were tilted up; and at the beginning of the Pleistocene period all these rocks, with their complex materials, were eroded away—the least-resisting constituents, such as tuff and serpentine, disappearing all but completely, and leaving as a residuum the less destructible garnets, etc. But the Pleistocene drift, in its turn, has furnished the material for alluvial sands, the garnets in which have thus undergone no less than three migrations from their original matrix.

In 1890, there were in north-eastern Bohemia 142 owners of garnet-diggings, employing altogether 346 workpeople, and the net value of the output (for the year) was £7,835. As before mentioned, the only mine now worked on a fairly large scale is that of Podseditz, where the garnetiferous drift, 9 feet or more in thickness, lies perhaps a couple of feet below the surface. L. L. B.

DEVONIAN IRON-ORE DEPOSITS OF MORAVIA.

Die Eisenerzlagerstätten des mährischen Devon. By Franz Kretschmer. *Jahrbuch der Kaiserlich-Königlichen Geologischen Reichsanstalt,* 1899, *vol. xlix., pages* 29-124, *with* 2 *plates and* 4 *figures in the text.*

This exhaustive paper is the fruit of the author's experience as a manager of mines in the district, an experience which extends over a great number of years.

In the Devonian of that portion of Moravia which stretches north-east of the March valley, and in the neighbouring tracts of Silesia, three distinct belts of iron-ore deposits may be mapped out. One of these (the most important from the industrial point of view) belongs entirely to the Lower Devonian, the second is very near the junction with the Middle Devonian, while the third is associated with diabases that come in near the junction with the Culm formation: the general strike of these ore-belts is east-north-east, coinciding with that of the underlying Archæan rocks and the overlying Culm.

The Lower Devonian, in this region, consists chiefly of a succession of quartzites and green schists (diabase-schists), with intercalated limestone-bands. The ores of the first belt are associated with the schists, and the whole formation is underlain by chlorite-gneiss and overlain by the Middle Devonian grauwackés.

The Middle Devonian consists of repeated alternations of these grauwackés with dark grey clay-slates, the former rocks predominating. As in the case of the underlying group, the strata are folded in a series of synclines and anticlines. Locally, some limestones are infolded with the grauwackès.

The Upper Devonian also presents a succession of grauwacké-sandstones and clay-slates, the former being very similar to those of the Middle Devonian, while the latter show far more clearly their sedimentary origin than the Middle Devonian clay-slates, being less micaceous and not so much cleaved. In the midst of the group appears a vast mass of diabase-amygdaloids, granular and compact diabases, diabase-porphyrites and limestones. With the amygdaloids are associated the iron-ore deposits of the third belt.

The overlying Culm, again, consists of an alternation of grauwackés and clay-slates.

This region, throughout the Devonian epoch, was the scene of repeated submarine volcanic eruptions. The volcanic ejectamenta (diabases) were pulverized and deposited on the sea-floor contemporaneously with the calcareous and argillaceous material that was, later on, compacted into limestones and clay-slates. Volcanic energy was greatest at the dawn of the epoch, but it slackened little by little as the long Devonian day drew to a close.

The lithology, petrography and mineralogy of the rocks are dealt with in considerable detail, and the author very fully describes the iron-mines. At Poleitz, where the workings go down to a depth of about 200 feet, three main deposits of magnetite have been found, containing on an average 49·2 per cent. of metallic iron and 18·5 per cent. of silica. In the Meedl district, are a western and an eastern group of deposits, divided by a barren mass of altered diabase-schists. The eastern group is by far the most important, and comprises three great bands of ore, varying in thickness from 6½ to 52 feet. The two lower bands are really a series of enormous lenticles folded into synclines and anticlines; and at the Eisenberg pit the ore-deposit reaches the exceptional thickness of 150 feet. The strike of the iron-ore deposits coincides in a general way with that of the diabase-schists and tuffs. The Meedl ore is, in the main, a compact red hæmatite largely impregnated with magnetite, and jasper is frequently associated with it. Further, there occur soft pulverulent magnetites and hæmatites (the outcome of the weathering of the more compact ores), containing more than 63 per cent. of iron and less than 6 per cent. of silica, while the compact ores average 54 per cent. of iron and 18 per cent. of silica.

The Pinke ore-field similarly comprises two groups of deposits—a northern (3 bands) and a southern (7 bands), separated by a mass of barren rock. These ores are largely associated with crinoidal and other limestones and siliceous ironstones. The best ore is a pulverulent red hæmatite, sometimes so strongly impregnated with finely-divided wad as to assume a brownish-black hue: the ore is then so crumbly that the wind blows it in clouds off the pit-heaps. Less common is a compact and fibrous hæmatite, sparsely impregnated with finely-crystalline or granular magnetite. The Pinke ores, on the whole, are far less magnetic than those of Meedl: the percentage of iron varies from 44 to 54 and that of silica from 17 to 25. Although the amount of phosphorus never exceeds 0·2 per cent., the general habit of the ores is such that they are not available for making Bessemer pig.

The author concludes, as to the formation of the Meedl and Pinke iron-ores, that their deposition was a secondary and hydrochemical, not a contemporaneous phenomenon. Metasomatosis took place on a large scale, whereby the outward form and structure of the original layers of limestone was preserved in the re-placing iron-ore seams. It appears probable that, from above downward, the limestones were gradually dissolved away as a double carbonate, while carbonate of iron was simultaneously precipitated in their stead: this being attacked by waters highly charged with oxygen, was decomposed to hydrated oxide of iron, and the carbonic acid thus set free acted as a solvent, starting a new cycle of similar reactions. Meanwhile, the hydrate of iron, losing its combined water, became red hæmatite, and this in turn was reduced to magnetite, but the process of reduction taking place unequally in the mass, the two varieties of ore are now found in association. The silica seems to have been derived from the diabase-schists.

The ores of the Sternberg field occur in great lenticles, which are apparently the separate portions of one band cut by successive faults. The workable ores are always found at the contact of the clay-slates and the diabase-amygdaloids, never in the diabase-rock itself: they are mainly brown hæmatites and magnetites, with percentages of iron varying from 32 to 52, and silica from 13 to 28.

For complete chemical analyses, full details of the methods of working, and the history of mineral industry in the region described, the reader should consult the original memoir, which is a storehouse of facts.

L. L. B.

COPPER-ORE NEAR LUDWIGSTHAL, AUSTRIAN-SILESIA.

Die Kupfererzvorkommen bei Ludwigsthal in Oesterreichisch-Schlesien. By JOSEF LOWAG. *Glückauf,* 1899, *vol. xxxv., pages* 739-740.

Near Ludwigsthal, and about 5 miles from Würbenthal, in Austrian-Silesia, is the so-called copper-adit (*Küpferstollen*), and a little further on the fallen-in shaft of the copper-mine, which consists of a quartz-lode 23 feet (from 6 to 8 metres) thick, bearing north-and-south, and dipping 70 to 80 degrees towards the east. The lode begins in the grey gneiss, and continues in Lower Devonian in a southerly direction. So long as the gneiss forms the enclosing rock, the lode is unproductive, with the exception of a few slight coats of malachite between the clefts and a few nests of copper-pyrites; and it is only when the lode leaves the gneiss and enters the black clay-slate of the Lower Devonian that it begins to be continuously ore-bearing.

The ores comprise copper-pyrites, bornite, earthy red oxide of copper and malachite, which latter generally fills the clefts and cracks of the quartz, while the other ores form clusters and detached masses in the lode or impregnate the quartz. In the shaft, the ores appear to be rich and abundant; but they cannot be followed up on account of water, for which reason the adit was started; but it ought to be extended about 130 feet, so as to reach the shafts.

As regards the geological and other conditions of this lode, it is due to an unmistakeable filling up of the cleft with quartz, which cuts the Lower Devonian strata, that bear north-east and south-west, in a north-and-south direction; and the same is the case with the strike of the neighbouring gold-quartz lodes in the Oelberg and Hohenberg. Whether the gold-quartz lodes cut through the copper lode (in which case great wealth of ore may be expected at that place), or whether the gold-quartz lode is cut, or entirely cut off, by the copper lode, is unfortunately not yet known, although it has been ascertained that the copper-ores contain gold and silver.

Throughout the whole length that the "copper-adit" traverses the lode in a horizontal direction, and where the grey gneiss forms the enclosing rock, the copper lode is unproductive. It is true that the parallel clefts, which are peculiar to all cleft-fillings, are present, cutting through the quartz-masses from floor to roof; but neither these clefts, nor the quartz-bands between them, show any mineral worth mining except an appearance of malachite or of brown iron-ore.

Where the gneiss forms the enclosing-rock, the copper lode contains, at the floor, a regular cleft that separates the gangue mass from the enclosing rock, which cleft appears to be filled either with a mixture of clay and quartz-sand or with clean quartz-sand. The filling mass contains abundant, but not very rich copper-ore, which comprises malachite, earthy red oxides and copper-pyrites, with nodules of sandy brown iron-ore underneath; and in one place this cleft forms in the gneiss a trough 20 feet (6 metres) thick, filled with clean quartz-sand, traversed by threads of earthy red oxide of copper. The copper-shafts were still accessible 15 years ago, the lode being here about 13 feet (4 metres) thick, and nearly vertical.

Intercalated with the unproductive, unchanged quartz is good ore-bearing rock; and where the ore appears the quartz is completely subdivided and cracked in all directions. All the cracks and crevices are filled with ore; and in places separate yellow and brown grains of quartz are also apparent in the ore. As a rule, the ore-bodies thin out at a longer or shorter distance, being replaced by sterile uncracked quartz; and it is therefore evident that the metallizing has only occurred where the quartz has been previously cracked. This same peculiarity in the copper lode also occurs in gold-quartz lodes; and these contain sterile rocks and also portions richer and poorer in ore, the richer portions being almost always in the neighbourhood of diorite-irruptions; and this circumstance must have been known to the old miners centuries ago, because they always made their explorations near to the diorite.

J. W. P.

PROBABLE EXTENSION OF THE BELGIAN COAL-FIELDS.

(1) *Probabilité de la Présence du Terrain Houiller au Nord du Bassin de Liége.* *By* MAX LOHEST *and* A. HABETS. *Annales de la Société Géologique de Belgique*, 1899, *vol. xxvi., pages lxxx-xci.*

(2) *L'Allure du Terrain Tertiaire appliquée à la Recherche de la Houille.* *By* GUSTAVE VELGE. *Ibid., pages xci-xcvi.*

(3) *Sur les Recherches de Terrain Houiller dans le Limbourg Belge et Hollandais.* *By* X. STAINIER. *Ibid., pages xcvi-cii.*

(4) *De l'Allure générale du Crétacé dans le Nord de la Belgique.* *By* BARON O. VAN ERTBORN. *Ibid., pages ciii-cv.*

(5) *Anciennes Recherches de Houille à Mouland et à Mesch (Hollande).* *By* ÉMILE HARZÉ *and* H. FORIR. *Ibid., pages cxxxiv-cxl.*

(6) *Le Relief des Formations Primaires dans la Basse et la Moyenne Belgique et dans le Nord de la France et les Conséquences que l'on peut en déduire.* *By* H. FORIR. *Ibid., pages* 130-155 *and* 1 *plate (map).*

Recent borings have shown that, although interrupted, faulted, and fractured, the Coal-measures extend from Liége through the Charleroi, Mons and Valenciennes coalfields, across the English Channel to Dover, and thence through Somerset into South Wales. On the other hand, they extend northward and eastward into Westphalia. The general aspect of this great formation is that of a basin whose southern rim is ridged up to such an extent as sometimes to be turned over on to its northern rim.

In Belgium, the Coal-measures are bordered on the north by Carboniferous Limestone, Devonian, Silurian and Cambrian strata: on the south side, the same succession is traced, but the older beds form an anticline, beyond which another Carboniferous basin appears. The question is whether, on the north of the known Coal-measures there is any hope of finding a similar fold of the Silurian succeeded also by a Carboniferous basin—from which latter, however, the Coal-measures shall not have been swept away by denuding agencies, as was the case in the southern basin. Mr. Lohest concludes in the affirmative, both on stratigraphical and on lithological grounds, and his conclusions are supported by Mr. Habets, who thinks that the hypothetical coal-basin will be found to lie somewhere north-west of Visé.

Mr. Velge draws attention to the fact that much useless labour and many costly borings in barren strata may be saved, if researches are guided by the principle of parallelism or concordance of tectonic features in superposed formations. Among the most distinguished exponents of this "working hypothesis," as British readers will remember, are Mr. Godwin-Austen and Mr. Marcel Bertrand. It is pointed out that this concordance is true of the strike and the dip: it applies to folds which may be seen repeated, like the concentric peels of an onion, from the Devonian up into the Tertiary. There is evidence that even the later Tertiaries participated in the final crumpling of the Condroz and the Ardennes, and thus it is plain that the last great uplift of the earth's crust dates from the end of Tertiary time. Mr. Stainier observes, however, that the principle of concordance of tectonic features does not always fit in with the facts, and recalls in this connexion the unsatisfactory result, from the mining-engineers's point of view, of the great sub-Wealden boring.

From the brief communications on old borings for coal, made half a century ago, on Dutch territory, near Mouland and Mesch, it would appear that coal was proved, that Lower and Middle, if not Upper, Coal-measures were struck, but that further exploration was abandoned for want of capital. These communications bear on the general discussion, in so far as they strengthen the evidence for the northerly extension (towards Limburg) of the Liége coal-field.

Baron van Ertborn asserts that the buried surface of the Palæozoic strata in northern Belgium is a plane surface, much like the cover of a desk, slightly inclined northward. He concludes that if the Coal-measures did formerly exist in the northern area of Belgium, they were swept away by the denuding agencies which were active during the long ages that elapsed between the close of the Carboniferous period and the earliest deposition of the Cretaceous sediments. Mr. Forir, however, has made a most exhaustive study of the question, based on the results of no less than 196 borings, and shows that instead of being in its entirety a gently inclined plane, the buried Palæozoic surface is in part broken up by sharp ridges and deep hollows. Further, it seems improbable that the Carboniferous in the north of Belgium should not have participated in the subsequent folding which affected the rocks of the neighbouring areas; and, being thus folded, the productive Coal-measures may indeed have been swept off the tops of the anticlines, but they will have been preserved in the synclines.

In summing up the discussion, Mr. Soreil points out the importance of making trial-borings in the neighbourhood of Eben-Emael and Eysden.

L. L. B.

COAL IN ASSOCIATION WITH CALAMINE, BELGIUM.

De la Présence du Charbon dans un Gîte Calaminaire. By JOSEPH LIBERT. *Annales de la Société Géologique de Belgique*, 1899, *vol. xxv.*, *Memoires, pages* 67-71, *with a figure in the text.*

One of the calamine-deposits worked by the celebrated Vieille-Montagne Company is at Pandour, near Welkenraedt, at the junction of the Coal-measure sandstone and the Carboniferous Limestone. Here the ore-body occurs in three masses, separated by barren red clays, and it is in the central mass that lenticles of carbonaceous matter have been found. The lenticles average about 30 inches in length, and 10 to 12 inches in thickness: although the distance between them varies from 6½ to 13 feet, they are joined one to the other, as a rule, by a very thin carbonaceous seam, but much more clayey than the lenticles themselves. This occurrence is in the midst of the calamine, about 6 feet away from the limestone-wall. Occurrences bearing some resemblance to this have been previously recorded elsewhere, but none of quite the same character. Further observation has shown that the calamine-mass is traversed by a thin band of Coal-measure shale, parallel to the coaly lenticles which pitch 45 degrees south-east; also that the ore below the lenticles is hard and of good quality, while the ore between them and the limestone-wall, although workable, is rather clayey and comparatively poor in zinc. This clayey stuff is thought to be a decomposition-product of calamine, and to have been brought to the spot later than the original ore-deposit. Similarly, the carbonaceous lenticles are of later date than the hard calamine and belong to the Coal-measure period. Chemical analysis of the coal yielded the following results:—Volatile matter, 20 per cent., and ash, 32·40 per cent. The ash was analysed as follows:—Silica, 12·00 per cent.; iron sesquioxide and alumina, 10·15 per cent.; lime, 0·07 per cent.; magnesia, 0·05 per cent.; lead protoxide, 3·76 per cent.; zinc oxide, 4·50 per cent.; sulphur trioxide, 2·50 per cent.; and traces of manganese peroxide. L. L. B.

METALLIFEROUS VEIN FORMED THROUGH ERUPTIVE ROCK, ARIÈGE, FRANCE.

Sur un Gîte de Magnétite en relation avec le Granite de Quérigut (Ariège). By A. Lacroix. *Comptes Rendus hebdomadaires des Séances de l'Académie des Sciences*, 1899, *vol.* cxxviii., *pages* 1467-1469.

A remarkably clear example of a metalliferous vein formed under the direct influence of an eruptive rock is afforded by the Boutadiol deposit of massive or crystalline magnetite, in connection with Quérigut granites in the department of Ariège; and study of this deposit leads to the same conclusions as does that of the axinite-rocks in contact with the granite of the Hautes-Pyrénées, showing the reality of the contributions made by the granite to the sediments which it metamorphoses, and also the indissoluble connexion existing between the production of these pneumatolithic emanations and the contact-metamorphism itself. J. W. P.

THE GEOLOGY OF THE BAYERISCHER WALD, GERMANY.

Geologisches aus dem Bayerischen Walde. By Dr. E. Weinschenk. *Sitzungsberichte der Mathematisch-physikalischen Classe der k. b. Akademie der Wissenschaften zu München*, 1899, *pages* 197-222, *with* 2 *plates and* 9 *figures in text.*

The author describes the geology of this region, characterized by alternations of granite and gneiss, the latter being extremely contorted. Among minerals of economic importance may be mentioned the occurrence of cupriferous pyrites, mined at Silberberg, and used chiefly for the production of vitriol. The deposit occurs at the contact between granite and gneiss in well-marked lenticular masses. The ores consist chiefly of magnetic pyrites, which never carries nickel; iron-pyrites; blende, with but little cadmium; argentiferous galena; small quantities of tinstone; magnetite; and ilmenite. It is noteworthy that particles of graphite also occur.

Graphite was formerly mined near Langdorf, but the workings have been abandoned on account of the poor quality of the mineral. At Passau, there is an important graphite-district, which has been worked for a considerable period, and is still being mined on a small scale by the peasantry, each landowner sinking a small shaft on his own property. The graphitic rocks are sometimes quite soft and earthy, at others compact and impregnated with iron pyrites. The contents of graphite are very variable, lying between 20 and 70 per cent., though the latter is rare. A graphite free from pyrites is more valuable than when impregnated with the latter mineral. Its mode of occurrence is quite analogous to that of the Silberberg ore-deposits, occurring in strings or lenticular masses within the gneiss. The occurrence is never very far from the contact between the granite and gneiss, and it is obvious that the existence of graphite is genetically connected with the presence of granite. The graphite-deposits frequently occur near inclusions of granular limestone, which are scattered throughout the whole area, and are characterized by the occurrence of numerous contact-minerals. Graphite generally occurs in more or less decomposed gneiss in the shape of uniform scaly impregnations, which seem also to indicate its secondary origin. The greater portion of this graphite has been used for some centuries for the manufacture of graphite-crucibles (known as Passau crucibles), which are made by crushing the rock and sifting or blowing out the finer crushed stone, by which means a concentrate containing 92 to 94 per cent. of carbon, and free from pyrites, is obtained; so that Passau graphite cleaned in this way is fully equal to the better grades of Ceylon graphite. H. L.

The OCCURRENCE OF OOLITIC IRON-ORES (MINETTE)) IN LUXEMBURG AND LORRAINE.

Das Vorkommen der Oolithischen Eisenerze (Minette) in Luxemburg und Lothringen. By Bergassessor L. Hoffmann. *Glückauf*, 1899, *vol. xxxv., pages* 640-645, *and* 1 *plate.*

These iron-ores occur over an area 12 to 18 miles (20 to 30 kilometres) broad and over 60 miles (100 kilometres) in length, extending over the south-western portion of Luxemburg, over the western portion of German Lorraine, the adjoining portion of French Lorraine, southwards to near Nancy, whilst a small point projects into Belgium. By far the greater portion of the deposit lies on the left bank of the Moselle, and forms part of a plateau which has received the name of the "Plain of Briey." The strata composing this plateau consists chiefly of Middle Jura or Dogger, below which Liassic beds occur, both having a general dip to the west.

The lower beds of the Dogger consist of clays, characterized by *Astarte Voltzi*, over which occur strata with *Trigonia navis* and *Ammonites Murchisonæ*. Above these follow the limestones of the Middle Dogger, the Longwy Marls, the Oolitic limestones of Jaumont, and the Gravelotte Marls. The *Trigonia-navis* and *Ammonites-Murchisonæ* beds contain in their lower portions several layers of oolitic iron-ores, separated by layers of sandstone, marl or limestone. The upper limit of these ferriferous schists is everywhere formed by a bed of marl characterized by its greyish-yellow colour and sandy structure. This bed is generally known as the hanging-wall marl, whilst the horizon of *Astarte Voltzi* is known as the foot-wall marl, and the intervening strata containing the beds of iron-ore are known as the iron-ore formation.

There are five main beds of iron-ore, called successively the Red Sandy, Red Calcareous, Yellow, Grey and Black Beds. In addition to these, there are a few beds of less importance, and generally only locally developed. The iron-ore formation attains its greatest development with a thickness of about 105 feet (32 metres), in the southernmost portion of Luxemburg and in the north of German Lorraine, thinning out towards the north and south. At its widest, the iron-ore formation has a thickness of 200 feet (61 metres), the above thickness of 105 feet (32 metres) being made up of the five main beds, whilst in the south the three lowermost beds alone occur, with a total thickness of only 15 feet (4½ metres), the formation being but 50 feet (15 metres) thick.

The formation, together with the over and underlying beds, is traversed by a great number of faults, some of which are of considerable importance, causing dislocations with a throw of 500 feet (150 metres).

The general composition of the workable portion of the individual beds is shown in the following table, in which, however, only the chief constituents are indicated:—

Name of Bed.	Black.	Grey.	Yellow.	Red Calcareous.	Red Sandy.
Iron, Fe	34	36	35	39	34
Lime, CaO	5	11	15	10	5
Alumina, Al_2O_3 ...	8	5	4	5	4
Silica, SiO_2	18	8	9	8	30

The chief constituents of the ore are hydrated oxide of iron, carbonate of lime, silica and alumina, together with smaller quantities of carbonate of magnesia, oxide of manganese and phosphoric acid. The ores average about 36 per cent. of iron, though selected samples may exceptionally reach 45 per cent. Lime varies from 5 to 20 per cent., silica from 7 to 34 per cent., and alumina from 2 to 10 per cent. The proportion of phosphoric acid is tolerably constant, averaging about 1·7 per cent. It is rare that all the layers are workable at the same time; as a rule, in one mine, not more than two beds are worth working, the workable thickness rarely exceeding 13 feet (4 metres).

The diameter of the oolitic grains which give the ore its peculiar structure averages 0·01 inch (¼ millimetre). They consist chemically of hydrated oxide of iron and amorphous silica, the latter remaining as a skeleton when the ore is treated with dilute hydrochloric acid. Probably the granules also contain phosphoric acid. The magma in which the oolitic grains are embedded is formed by calcite or marl, and occasionally by quartz. There is no sign of stratification or parallel structure. The ores are almost universally traversed by calcareous partings, forming masses from 3 to 50 feet (1 to 15 metres) in length and up to 1½ feet (½ metre) in thickness; or else they form ellipsoidal inclusions. Their structure is identical with that of the ore, from which they are distinguished by their greater content of lime, great hardness and paler colour. Sometimes these partings are so numerous that the entire bed is no longer worth working. When present in smaller quantity they are not a disadvantage, as they can be used for stowing the worked-out portions. The transition from these barren partings to the true ore is quite gradual. The boundaries between the beds of ore at the roof and floor are but rarely sharp, there being here also a gradual transition. When the walls consist of oolitic limestone, the iron-contents of the oolitic grains diminishes gradually, whilst where the roof or floor is of marl or sandstone, individual oolitic grains continue in these rocks and disappear little by little.

Luxemburg.—The iron-ore formation covers an area of about 9,000 acres (37 square kilometres). In addition to the five main layers, a bed occurs in places above the Black Bed, which is known as the Brown Bed, and furnishes, like the former, a siliceous ore. Most of the beds are workable in places, with the exception of the Red Sandy Bed. The Grey Bed, 10 to 13 feet (3 to 4 metres) in thickness, and the Red Calcareous Bed, 6 to 13 feet (2 to 4 metres) in thickness, are the most important, and are generally workable. In 1897, Luxemburg produced 5,360,856 tons of minette-ore. It is calculated that there are still 300 000,000 of tons of ore in existence, of which 123,000,000 are suitable for export, and 177,000,000 can be smelted locally. Remembering that about two-thirds of the ore is exported, it may be reckoned that the available ores suitable for export will be exhausted in 37 years, whilst those suitable for the local blast-furnace practice will last for about 80 years.

Germany.—The iron-ore formation of Lorraine occupies a length of 37 miles (60 kilometres) and a breadth of 2 to 9 miles (3 to 15 kilometres), covering an area of 350,000 acres (1,400 square kilometres). Of the five main beds, the Red Sandy Bed pinches out near the river Orne, and the Red Calcareous Bed near St. Privat. In addition to the five main layers, there are two brown layers, which are workable. The most important, however, is the Grey Bed, averaging 11½ feet (3·5 metres), and, exceptionally, 33 feet (10 metres) thick. The Black Bed is on the average 6½ feet (2 metres) thick, and is workable in many places. The Lower Brown Bed appears to be workable almost whereever it exists. In the area north of the river Fentsch, the hectare (2·47 acres) produces from 95,000 to 165,000 tons of ore; between the rivers Fentsch and Orne, 75,000 tons; between the rivers Orne and St. Privat, 40,000 to 65,000 tons; and south of the last-named place, 25,000 tons.

In 1897, 5,960 workmen were employed in these iron-ore deposits of German Lorraine, and produced 5,360,586 tons of minette-ore. If the production remains at its present figure, the available ore will be exhausted in about 370 years. This figure is, however, much too high, because the amount of ore produced increases year by year. In the three years 1895 to 1897, the increase has amounted to 37 per cent., and there is no doubt that it will continue throughout a long period.

France.—It has been calculated that there exist 135,000 acres (540 square kilometres) of workable ore, which are divided into four basins, known respectively as the Longwy, the Moselle and Meuse, the Orne and the Nancy basins. The first and last fields are those in which most work has been done up to the present. In addition to the five main beds, a green bed has been cut in several bore-holes below the Black Bed. The Upper Brown Bed is also found to exist in some places. The Grey Bed is also found in France, the most important sections averaging from 6 to 13 feet (2 to 4 metres) of workable ore, but, exceptionally, 29 feet (8·8 metres). In the Nancy basin, there are altogether seven beds, which have not yet, however, been correlated with those of the northern basin. In 1897, the produce amounted to 4,120,000 tons.

Formation.—Messrs. Giesler and Braconnier are of opinion that these ironore beds have been formed by sedimentary processes, and are, therefore. original beds. These views have been questioned by many authorities, it having been often assumed that the formation was due to metasomatic processes—that is to say, that iron was introduced simultaneously with the removal of existing constituents of the rocks. The author has in a previous paper shown that according to his opinion the first-named view is the correct one. This iron-ore occurrence is one of the greatest known anywhere. Of all the ores got in the German Empire in the year 1897, about 53 per cent. came from the mining districts of Lorraine. Unfortunately, a considerable portion of this minette-ore is exported to Belgium and France, and it is therefore of the highest interest that the railway-tariff should be lowered, and that the river Moselle should be canalized, in order to afford an opportunity of conveying these ores to the blast-furnaces of Germany, seeing that these furnaces are at present compelled to draw a considerable proportion of their ore-supplies from foreign countries, especially Sweden and Spain.

H. L.

AMBER IN EAST PRUSSIA.

Das Bernsteinregal in Ost-Preussen. *By* Dr. H. Brassert. *Zeitschrift für Bergrecht*, 1899, *vol. xl., pages* 282-298.

The most extensive occurrences and the most important winnings of the amber of the Baltic coast are in the province of East Prussia, and there (from the strictly legal point of view) the mineral is State property. As a matter of fact, however, the State has neither worked amber nor trafficked with it on its own account: the exploitation and sale have been for a long series of years practically monopolized by Messrs. Stantien & Becker, of Kœnigsberg. At the present moment, the underground workings of the district of Samland are the chief sentre of activity of the amber-exploitation, and the following geological data regarding that district are quoted from a memoir to which more detailed reference will be made further on:—

The occurrence of amber in Samland is associated with the Glauconite formation. This is made up of sands and of loams characterized by a certain percentage of glauconite, which were laid down in the seas of the Tertiary period. According to the opinions universally held by geologists, during the formation of these deposits, and mainly during that of "blue earth," belonging to the lower portion, the indurated resin proceeding from several species of conifers (more especially from the amber-pine) was floated into the bay, where the glauconitic strata of Samland were being laid down. At that period, and even before Tertiary times, vast forests of conifers must have covered a large portion of Northern Europe, especially Scandinavia. The amber occurs, then, as a secondary deposit, disseminated throughout the "blue earth." This is a loam, greenish-grey when dry, nearly black when wet, rich in fine grains of quartz and glauconite.

This blue earth varies in thickness, and the amber is most abundantly disseminated in its lower portion—within a stratum measuring from 30 to 60 inches in height. The practicability of working is conditioned not only by the percentage of amber and by the thickness of the amber-bearing seam, but also by the amount of barren blue earth which overlies this, and by the number and thickness of water-bearing sands which are commonly interbedded with the blue earth.

From July 1st, 1899, the amber-industry entered upon an entirely new phase—the Prussian State having acquired by purchase the whole belongings of Messrs. Stantien & Becker, and thenceforth the State will itself work the mineral and trade with it on State account.

In 1899, the Government published an explanatory memorandum specifying the amounts which went to make up the total purchase price of £487,500. and also an exhaustive memoir which dealt with the amber question in a manner that did full justice to its importance. It set forth clearly the reasons which had finally determined the Government, despite undeniable difficulties, to take over the amber-industry as a State concern, and thus to put an end to the intolerable grievances fostered by private monopoly, aiming thus at a solution which would be welcomed as equitable by all alike, and especially by the province of East Prussia. The memoir is divided into two parts, the first dealing with the Crown rights to the mining of amber in East Prussia, and the manner in which they had been utilized; and the second with the question of sale. The two first sections of the first part are especially devoted to the legal aspect of the question and to the utilization of the Crown rights: they possess an interest which is really general and permanent, quite apart from the problem for which it is assumed that a solution has now been found, Here are laid down the grounds of fact and of law upon which the now completed transformation of the amber-industry is based. The varying legal conditions, according as one is dealing with the province of West Prussia or with that of East Prussia, or with the deep-level workings of Samland, are portrayed. Then follows an account of the manner in which the Crown rights have been exercised from olden times down to recent days, with a description of the four different methods of winning amber. These sections are stated to be merely introductory and "for information," but on account of the exhaustive nature of the memoir we can only briefly refer to them here:—

"The right to appropriate amber has assumed different forms in the coastal provinces of Prussia, where it occurs in varying quantity. It is based in part on general principles of jurisprudence, in part on legislative provisions peculiar to each province—and derived either from the right of occupancy of the ground-landlord, neighbouring owner, or discoverer, or from foreshore rights.[*] In those districts where the State has a prior claim on amber, as, for example, in Old Pomerania, Nearer Pomerania and Further Pomerania, the Crown confines itself to the mineral cast up by the waves, basing its right on the foreshore, which, according to Prussian law, is the property of the State.[†]

"Over the territory comprised within the modern province of West Prussia various special provisions are in force, according to which the amber occurrences belong in part to the Crown, in part to the ground-landlord, and in part to the city of Danzig.[‡] But the legal aspect of the question in the province of East Prussia is as different as it well can be. This province is even nowadays still the main source of amber, but very early in the Christian era wide-reaching claims on behalf of the rulers of the land as to the ownership of the mineral were crystallized into law. These claims, far more exacting and extensive than mere foreshore rights (such as those existing in other parts of the country) have been ever since the domination of the Teutonic Order of Knights, laid down in innumerable decrees, regulations concerning amber, digests of law, etc., dating as far back as the middle of the 13th century.[‖] Many a fierce legal conflict as to the actual delimitation of the Crown rights has been waged over these old documents, but they cannot be taken into account nowadays, as two recent laws have placed beyond doubt the postulate that the Treasury rights in East Prussia extend to all amber whatsoever, whether it be found on the foreshore, on the beach or inland.

"Further, the universal State ownership of all amber in East Prussia was recognized in the Provincial Law and codified at the beginning of the present century. The East Prussian provincial code of 1801-1802, reads in Supplement 228 to section 80, Part II., Art. 15:—

(1) Amber is the property of the State, and no one is permitted to traffic with the raw mineral, nor any one with the manufactured article, without special authority so to do, on pain of confiscation of the goods or payment of their value, as well as punishment by fine or personal durance.

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[*] Further details on this point will be found in Von Brünneck's *Das Recht auf Zueignung der von der See Ausgeworfenen und angespülten Meeresprodukte und das Bernsteinregal* (The Right to appropriate all that is cast up or washed ashore by the Sea and the Crown Monopoly of Amber), Konigsberg, Prussia. 1874.

[†] Compare section 80, Part II., Article 15 of the Code: "Harbours and sea-shores, and what is there washed up or cast up by the sea, are according to common law the property of the State."

[‡] Compare Digest of the Provincial Laws of West Prussia, published April 19th, 1844 (page 103), sections 73 to 80, Part II., Article 15 of the General Code; Law concerning the Extension of the West Prussian Provincial Code to the City of Danzig and its Dependent Territory of February 16th, 1857 (page 87).

[‖] See also Von Brünneck, *op. cit.*, where the above-mentioned deeds are catalogued, and their more essential parts reproduced in print; also Tesdorff, *Gewinnung, Verarbeitung und Handel des Bernsteins in Preussen von der Ordenszeit bis zur Gegenwart*, (Winning, Dressing and Traffic of Amber in Prussia, from the time of the Order of Knights to the Present Day), Jena, 1887.

(2) All amber whatsoever, whether scooped up or dug out, or obtained in any other fashion, must be delivered up at the Amber Chamber in Kœnigsberg, whereupon to those who have found the amber upon their own estate there shall in recompense be paid one-tenth part of the value of the amber so delivered, due estimation thereof having been made by the aforesaid Amber Chamber.

"These rights of the Treasury received a fresh sanction in the Law of February 22nd, 1867 (digest, page 272), whereby firstly the punishment to be meted out for illegal appropriation of amber was settled; and, secondly, the provisions of the Civil Code regarding amber were incorporated in Article 4 of the East Prussian Provincial Code, as follows:—

(1) Amber, whether found in the Baltic or on the shores thereof, as also in the Frisches Haff and the Kurisches Haff, or whether it occurs inland, is reserved as the property of the State.

(2) Whosoever, without being authorized to collect amber, by chance finds, fishes or digs it up, becomes thereby possessed of the rights and duties of a finder.[*]

"Of the various methods of winning amber that of mining it in deep levels is nowadays by far the most important, and although the Crown rights in East Prussia are all-embracing, this particular method of winning tends so inevitably to limit the practical exercise of the rights of the State that in the matter of deep-level mining these may be denoted as imperfect. It may be quite true that the amber hidden away in the soil of East Prussia is the unquestioned property of the Prussian State: but the assertion of this right is barred by the right of the landowner. If the latter chooses to resist, no legal weapon lies ready to the hand of the State whereby he can be forced to disgorge. The General Mines Act of June 24th, 1865, is not applicable to amber. While this Act allows, under certain provisoes, any person to seek and win minerals, even on other people's property, this is not the case with amber. The preamble of the Act accounts for the exclusion of that mineral on the grounds that amber in Prussia was never at any time made subject to the provisions of general mining jurisprudence, and that moreover the winning thereof was fully dealt with in the Provincial Codes. In this connexion, however, one should bear in mind the different conditions which prevailed when the Mining Code was drawn up, as amber was then to be got without engaging in actual mining operations. The legal situation in East Prussia presents, therefore, this anomaly: that the landowner cannot, without leave from the Treasury, proceed to win amber on his own estate; while the Treasury cannot give effect to the Crown rights, or even undertake exploration-work on private property without the consent of the landowner. The bearing of this state of affairs in relation to deep-level workings is the more important that, on Government property, geological research has so far failed to reveal any amber-deposits that give the slightest hope of being worth the cost and trouble of working.

"In the time of the Teutonic Order of Knights[†] the dwellers by the sea on the coast of Eastern Prussia were bound to collect, fish and "spear"[‡] amber, and in return for a slender wage to deliver it up to the officers of the order.

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[*] General Code, Part I., Article 9, sections 9 to 22, and 43 to 72.

[†] This was a military brotherhood, which in the Middle Ages gradually conquered and Christianized the remoter parts of Prussia, then inhabited by the Pagan Vends. The knights built castles and churches, taught the conquered tribes the Gospel and the arts of peace, and played in some respects much the same part as our missionaries do nowadays in the wilds of Africa.—L. L. B.

[‡] By "fishing" was understood the catching up of amber in nets from the sea-water [probably in the lagoons], and by "spearing" the grubbing out of the mineral from the sea-bottom by long poles or pikes and then drawing it up in so-called "traps."

The Grand Master, Duke Albert, in 1518, with the view of making more profit out of the monopoly, entered into contracts with various merchants from Königsberg, Danzig, Lübeck, Augsburg and Antwerp, whereby new markets were opened up to the mineral even in far-off countries. But as the cost of management and winning increased, and the profits correspondingly decreased, the successors of Duke Albert sought to regain the unrestricted enjoyment of the monopoly and to free themselves from contracts which had become burdensome. But a full measure of success did not attend these efforts until the time of the Great Elector, who in 1644 issued exhaustive Regulations regarding Amber. The territory where the mineral occurs was split up into several districts, each under the headship of a so-called 'Beach-ranger.' The duty of the Ranger was to exercise constant supervision over those shore-dwellers who were bound to win amber, and to guard against fraud. The better pieces of amber were sold at public auction, while the pieces of less value were sold at a fixed scale of prices to the guilds of amber-turners, who flourished in such cities as Lübeck, Kolberg, Köslin, Stolp, Danzig, Elbing and Königsberg. During the whole of this time the Government rights were vigorously upheld. Severe punishment was meted out to those who stole amber, sentence being passed by a special so-called 'Amber Tribunal.' In order to obviate the chance of secret misappropriation, no worker in amber was allowed to settle within the territory of the Order of Knights, and every grown man was bound every three years to swear the so-called 'Shore-oath' before the officers, to the effect that he would never misappropriate any amber himself and that if he became aware of such misappropriation on the part of any one of his relatives he would denounce the guilty person to the authorities.[*] The successors of the Great Elector issued repeatedly new regulations regarding the utilization of the State monopoly, but on the whole the system underwent no essential change until the beginning of the present century.

"Then, the constant diminution in the profits of the monopoly, and the need of improving the revenues of the State, which made itself strongly felt after the events of 1806-1807, led the Government to consider the advisability of changes in the system. In 1811, the monopoly was farmed out, first of all to a syndicate, whereof the chief member was Mr. Charles Douglas, and later on, to him alone, and in his hands it remained till 1835. During those years the quit-rent varied somewhat, but the annual average was £1,500. Although the burden of obligatory winning of amber and the restrictions imposed by the 'shore-oath' were thus taken off the shoulders of the coastal population, the condition of that population was still far from prosperous. The Government thereupon resolved in 1836 to farm out the monopoly to the dwellers by the sea. Separate contracts were signed with the large landowners whose property abutted on the coast, and the inhabitants of the fishing-villages formed amber-farming syndicates under fairly autonomous management. The total yearly income to which the quit-rents amounted averaged, as before, £1,500. This state of affairs lasted till 1867. The economic condition of the coastal districts had certainly improved under the new *régime*, but the latter was attended with so many disadvantages in other respects that in 1870 a complete change of system was resolved upon. Thereby a new road was opened up not merely to the winning of the raw mineral, but to the trade in and manufacture of amber. In the contracts with the dwellers by the sea-shore, those who paid the agreed quit-rents were not only allowed to 'collect, fish, and spear' amber, but also to dig it in the cliffs or banks. Now the digging was carried on in a very unmethodical fashion in open workings: and the smaller syndicates, having but little capital to back them, dug the mineral in a most wasteful manner. They under-cut the cliffs, so that these fell an easy prey to the waves of the sea, and thereby hastened the destruction of the coast-line, especially of the western coast of Samland. The fall of the coast-hills resulted in the overwhelming invasion of blown sands, to the manifest damage and ruin of the tilled fields. The consequence was that the conditions of agricultural labour in those districts steadily grew worse, and a mass of unemployed hands drifted to the amber-workings.

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[*] See Tesdorff, *op. cit.* pp. 20 *et seq.*

"As a further consequence, in concluding fresh contracts for the winning of amber on June 1st, 1867, the Prussian Government expressly withdrew the permission hitherto granted to the dwellers by the sea-shore to dig for the mineral in the cliffs or banks, and reserved to the Treasury complete freedom to determine what should be done in that matter. To the larger landowners permission was given to dig for amber only up to December 31st, 1869, under special provisoes for compensation in case of damage incurred through their workings. In the course of the following year permission was extended to Messrs. Stantien & Becker, and to a few other contractors, to start open diggings on the sea-shore under certain restrictions. But the enormous expenditure which this entailed, and the unceasing destruction of the sea-cliffs, combined with the initiation of the deep-level winning of amber to bring about the stoppage of open workings in 1874. Amber has in recent days been won only by dredging and diving, by collecting, 'fishing and spearing' along the sea-shore, and by deep mining.

"In 1859, dredging operations, which had been carried on for the purpose of widening the navigable channel in the Nehrung, near Schwarzort, having disclosed the presence of large quantities of amber, Messrs. Stantien & Becker sought in July, 1861, permission to dredge for the mineral, and on May 1st, 1862, the Government signed a contract to that effect, holding good till 1868. On the expiry of this contract, the Government, desirous of favouring free competition, offered the right of dredging at public auction; but, failing to receive any bids, the authorities concluded a fresh contract with the above-mentioned firm, to hold good till 1882. The results obtained by dredging became yearly more and more remarkable, not only from the abundance, but from the beauty of the mineral, much to the advantage of the State treasury. On the expiry of the second contract, the dredging-rights were again put up at auction, but again failed to attract bidders, and they were again farmed out to Messrs. Stantien & Becker up to November 30th, 1900, in consideration of an annual payment of £10,000. In 1886, however, the falling-off in the amber-harvest was so serious, owing doubtless to the exhaustion of the uppermost layers of the bottom of the Haff or lagoon, that the contractors declared that they were working at a loss, and gave notice to terminate the contract on November 30th, 1890. Once again the endeavour to farm out the dredging-rights by public auction proved utterly fruitless, and since then dredging-operations for amber have been suspended.

"In 1869, for the first time, the right of winning amber along the foreshore of Gross Dirschheim, Brüsterort and Klein-Kuhren, by diving, was put up at public auction, and was granted to the sole bidders, Messrs. Stantien & Becker. In 1874, this firm purchased similar rights along the Palmnicken foreshore, in 1881 along the contiguous shores of Sorgenau, Kraxtepellen and Gross-Hubnicken as well, and in 1885 along those of Kreislacken and Marscheiten. Diving-operations were conducted in all these localities on a great scale, with very profitable results for the contractors. But it was only natural that in the course of years the amount of amber got by diving over a comparatively restricted area should decrease. The Treasury suffered a corresponding diminution of revenue. The last contract for diving, signed with Messrs. Stantien & Becker in 1885, expired on May 18th, 1891. Further offers made by that firm were rejected, because the persons who had purchased the right to win amber along the beach complained that their interests had suffered injury through the diving-operations. When in 1893, several landowners on the Samland coast of the Baltic prayed for the grant of diving-rights the Government maintained its previous refusal.

"The winning of amber by collecting, fishing and spearing along the shore, in accordance with the practice which has obtained since 1837, is in the case of Crown property put up at public auction, and in the case of other property given out freely, not, however, as in former days, to amber-farming syndicates, but to the several landowners, municipalities, etc., whose lands abut on the shore. Not only is this system of free grant favourable to the occupier from the economic point of view, but it appears indispensable when one considers that the farming-out of the right to third parties would lead to endless bickerings between the seekers for amber and the occupiers of the land. Wherefore the right to win amber along the beach has been freely conceded to 32 communes and landowners. Messrs. Stantien & Becker, so far as the Crown property along the Samland coast was concerned, obtained the right at public auction, and in respect of their own property got it by free grant, like other landowners. Meanwhile the amount of amber obtained along the beach has of late steadily diminished, and several of those to whom the right had been farmed having given notice to terminate their contracts, the State revenues from that source have correspondingly decreased. The total quit-rent for beach-winning now amounts to only £350 per annum, whereas in 1867-1879 the annual average was £1,400, and in 1879-1885, £650. From those portions of Crown property which have been leased for amber winning to others than Messrs. Stantien & Becker, the State at present derives the insignificant income of £105.

"As already mentioned, the method of winning by deep level, that is, by mining the amber-bearing stratum or blue earth, is nowadays, and probably will be for a long time to come, the most profitable and the most widely followed. At present these mining operations have been carried out only on such portions of the western coast of Samland as had become the absolute property of Messrs. Stantien & Becker, property which they mostly acquired many years ago. Earlier endeavours, attempted on Crown property as well as on that of other private owners, to win amber by mining, met with failure. For instance, in 1873, at Nortycken, about 2 miles south of the coast, an unsuccessful attempt was made to start a Government mine. A shaft, in part lined with iron, in part with masonry, was sunk at great expense, but the lie of the strata in the neighbourhood was such that it was found impossible to drive levels along the amber-bearing stratum, and the attempt was given up in 1879. Meanwhile, by a contract dated November 20th, 1875, the Treasury had conceded to Messrs. Stantien & Becker the right to mine amber over an area of about 15 acres of the Palmnicken estate for the next 8 years in consideration of the payment of £2,000 for every *morgen* of productive area in the mine. The amber production from underground workings proved abundant beyond all expectations, and by dint of unceasing efforts Messrs. Stantien & Becker were successful in opening up constantly new markets to keep pace with the increasing production. In the course of years the original contract was supplemented and completed by several subsidiary contracts, whereby further areas were leased to the firm, and on the other hand the quit-rents payable to the State were gradually increased. In the third contract, of July 16th, 1883, the right to mine for amber was assigned to this firm on further portions of its own estates of Palmnicken, Kraxtepellen, Bardau, Gross- and Klein-Hubnicken. The forfeit to be paid for each *morgen* worked was fixed at £2,500, and the minimum annual quit-rent to be paid, quite independently of the progress of the mining operations, was fixed at £15,000.

"The contract was to hold good for 18 years (up to November 4th, 1901), but the firm was allowed to give notice of termination, provided this took place not later than November 4th, 1891, or November 4th, 1896. In 1891, it became evident that the areas conceded by the contract of 1883 were not extensive enough to permit of well-planned mining operations. Thereupon, in response to the application of the contractors, mining rights over further areas were leased to them, but the forfeit payable for each *morgen* had now risen to £2,625, and the annual quit-rent to £33,880. The raising of the minimum annual quit-rent was justified on the ground of the stoppage of dredging for amber in the Kurisches Haff on December 1st, 1890; but it was agreed on both sides that if the right to dredge were profitably disposed of elsewhere, the annual quit-rent for deep-level workings would be again reduced to £15,000. The Palmnicken mine was worked from 1874 onwards, but on account of the exhaustion of that portion of the field, operations were brought to a close there in February, 1896. At present workings are being pushed north of the western coast of Samland in the Anna mine. The amount of raw amber obtained from deep-level workings during the last 25 years is very considerable. During the years 1892 to 1896 (both inclusive) the annual total averaged 498 metric tons. L. L. B.

LIGNITES IN THE COLOGNE BASIN, RHINE PROVINCE.

Das Braunkohlenvorkommen in der Kölner Bucht. *By* Bergassessor Dobbelstein. *Glückauf*, 1899, *vol. xxxv.*, *pages* 753-763, *and* 2 *plates.*

The Cologne basin is closed towards the south and open towards the north, its deepest axis being more or less exactly indicated by the course of the river Rhine. The rim is formed of Devonian strata, upon which Tertiary rocks of Oligocene age repose uncomformably. They only crop out at the foot of the hills, being covered by alluvial deposits in the valleys. The thickness of the Oligocene strata is considerable, a bore-hole of a depth of 820 feet (250 metres), put down near Brühl, not having traversed them. As the roof of these deposits is a further 246 feet (75 metres) above the level of the mouth of the bore-hole, the greatest known thickness of the Oligocene rocks in the basin of Cologne may be taken as above 1,060 feet (325 metres). The strata consist chiefly of plastic clay, quartzose sand, and beds of lignite, with, in some places, various igneous rocks, chiefly tufaceous. The total length of this deposit may be taken at 15½ miles (25 kilometres), average width 3 miles (5 kilometres), and its thickness at 89 feet (27 metres), but in some places it reaches 340 feet (104 metres). The cubic contents of the deposit, therefore, amount to 4,683,000,000 cubic yards (3,575,000,000 cubic metres) of workable coal. The average composition of the principal deposit of lignite, dried at 212° Fahr., is as follows:—

	Per cent.
Carbon	66·38
Hydrogen	5·54
Oxygen and nitrogen	23·55
Ash	5 to 6

The hygroscopic moisture varies between 19·68 and 23·55 per cent. The quantity of water in the freshly-mined coal is a very important element for practical purposes. It averages 48 per cent., varying between 62 and 39 per cent. The percentage of ash varies between 4 and 10 per cent.

The modern method of mining consists almost exclusively of stripping and opencast working, various methods of haulage, including aerial wire-rope haulage, being employed.

This coal is generally made into briquettes, the production of which is due to the property of the crushed lignite to cohere into a compact mass, cemented together by the oil and resins present, when exposed to a high pressure, say up to 1,500 atmospheres. The lignite, as it comes from the mine, is crushed in rolls, dried until its water contents are reduced to 16 or 18 per cent., and then transported by means of a screw-carrier to the presses, in which the briquettes are moulded. Each briquette-press produces 1,000 tons of briquettes annually, for which 393,000 cubic yards (300,000 cubic metres) of coal, as standing in the deposit, are consumed. From 30 to 35 per cent. of the total coal got is used for firing. H. L.

PRECIOUS-STONE PLACERS NEAR HINTERHERMSDORF, SAXONY.

Die Edelsteinseife des Seufzergründels bei Hinterhermsdorf in Sachsen. *By* Hans Oehmichen. *Zeitschrift für Praktische Geologie*, 1900, *pages* 13-17, *with two figures in the text.*

These deposits have been known for the last 300 years, and have been often described by the older writers. They occur on the banks of a small streamlet, which has carved for itself a deep runnel out of the *Brongniarti*-zone of the Cretaceous sandstone of Saxon Switzerland. This Quader Sandstone is the dominant rock of the district, here and there covered by Drift or broken through by basalt. Where the streamlet flows through the Drift-formation, sands are found, so rich in magnetite and titanite as to be almost black. If a handful of the sand be taken up it is easy to pick out of it fragments of hornblende, augite, bronzite, beautifully coloured and sometimes fairly large jacinths, and ceylanite. More careful examination reveals zircons, spinels, grains of glass-green diopside, and prisms of apatite. Corundum also is said to have been obtained. At one time it was proposed to start ironworks in the neighbourhood, in which the sands would figure as the ore-supply, but the idea appears to have been abandoned.

The original rock from which these sands were derived was first recognized by Prof. Beck, in the course of his official mapping of the district. It is a boss of Tertiary olivine-hornblende basalt, which crops up west of the Hohwiese with associated tuffs and breccias. In these breccias are curious inclusions as big as a man's fist, extremely rich in spinel and bronzite: they are comparable, in the author's opinion, with the diamantiferous garnet-diopside masses of the Kimberley district, and bear out Sir A. Geikie's remark that there is a definite set of conditions of temperature and pressure (as yet unknown to us) connected with pyroclastic phenomena, which peculiarly favours the formation of various precious minerals. L. L. B.

THE IRON-ORE DEPOSITS OF THE KERCH PENINSULA, SOUTHERN RUSSIA.

Note sur les Gisements de Minerais de Fer des Presqu 'Iles de Kertch et de Taman (Russie). By — BAYARD. *Annales des Mines*, 1899, *series* 9, *vol. xv., pages* 505-522, *and* 1 *plate (map).*

These deposits have been known since 1832, but after one or two unsuccessful attempts to turn them to account (from 1840 to 1860), they remained buried in oblivion till 1896. Then a group of Russian and foreign engineers made a fresh study of the ores, with the result that they are now reckoned among the most important deposits of the kind in the Russian Empire. Mining-plant on a big scale has been put down, narrow-gauge railways built, and blast-furnaces were in course of erection when the author wrote his paper.

The peninsulas of Kerch and Taman exhibit a series of synclinal basins and anticlinals, the formation of which is doubtless connected with the upheaval of the Caucasus on the one hand and the Crimean Chatyr Dagh on the other. With these orogenic movements, which are still going on, but with diminished intensity, may be associated the mud-volcanoes and naphtha-wells characteristic of the region, as well as the great eruption of a century ago.

The two mining-basins of Kerch and Kamysh Burun are separated by the steep anticlinal of Jerzhava: the basins on their further sides flatten out, affording a wide surface suitable for opencast workings. The ore-deposit, at first hidden beneath the buildings of Kerch, reveals itself by its characteristic yellow colour at the very gates of the town, close by the Tartar mosque, and is seen to strike northward through the suburban gardens with a steepish dip of 45 degrees. It then turns north-eastward, disappears for a time, re-appearing south of Katerless: all the wells dug in that village have struck the ore, which belongs to the upper division of the Pontic (Lower Pliocene), before getting down to the water-bearing stratum of the Meotic (Lowermost Pliocene) limestone. Ultimately the strike curves round southward to the bay. The area of this mining-field is rather more than 7,800 acres, and the available ore is estimated to amount to 100,000,000 metric tons, of which about a tenth can be got by opencast working. About 2 miles to the north-east lies the small basin of Baksy, the area of which is about a quarter of that of the Kerch basin.

Midway up the cliffs of Kamysh Burun (130 feet is their average height), the iron-ore, in the form of a broad brown belt, can be seen from the deck of any vessel making for Kerch Roadstead: as the cliffs weather away, the ore-masses break off and are piled up on the beach in tumbled blocks. By means of this cliff-section geologists have been enabled to follow the course of the deposit inland. It extends southward to Lake Churubash, and the ridge of Sarmatic (Upper Miocene) limestone on the farther shore of that lake was at one time held to denote the termination of the Pontic (Lower Pliocene) basin, and therefore of the iron-ores. They reappear, however, still farther south, constituting the basin of Eltingen. It is estimated that the available ore of Kamysh Burun and Eltingen together amounts to between 150,000,000 and 200,000,000 metric tons. Southernmost of all lies the basin of Yanish Takil, where indeed the outcrops in the cliffs are poor in iron-ore; inland, however, the basin flattens out, and proves to be rich enough to warrant working.

As seen in the cliffs of Kamysh Burun, the most complete exposure known of this ore-deposit, it is made up of a shell-bed floor bound together by a ferruginous cement (*podrudok*), ferruginous clays, 10 to 12 feet of yellow, brown and black pisolites, followed by black iron-sand with as much as 15 per cent. of manganese, a 20 inches thick cockle-bed, the shells of which are filled with manganiferous iron-ore and vivianite-crystals, then a band of sandy siliceous ore, and finally a roof of clay bespattered with gypsum-crystals. But it is rare to find all these beds together: generally the deposit consists of brown pisolitic bands traversed by blackish veins, which, where they are thickest, are rich in vivianite-crystals. At Katerless and Eltingen, the black iron-sand with 15 per cent. of manganese is predominant.

The author tabulates 21 chemical analyses of the ores of Kamysh Burun and Kerch, from which the following percentages may be quoted:—

	Minimum.	Maximum.
Iron	25·90	44·90
Manganese	0·35	17·30
Phosphorus	0·60	3·25
Sulphur (Kerch ores only)	0·02	1·00

The ores have been tried at the Ougrée ironworks in Belgium and by the Briansk Company, Yekaterinoslav, and it has been shown that they yield satisfactory results when smelted alone, as well as in mixture with other ores. The new ironworks established at Kerch will use the ore largely in the form of briquettes (to which lime and coke-dust is added), agglomerated together by Biétrix presses. L. L. B.

COAL IN SERVIA.

La Houille en Serbie. By Eduard Heguer *and* Jules François. *Publications de la Société des Ingénieurs sortis de l'École Provinciale d'Industrie et des Mines du Hainaut,* 1899, *series* 3, *vol. viii., pages* 397-402.

Coal-deposits are abundant in Servia, but mining operations are conducted on methods scarcely less primitive than those of the Chinese, and in the whole country there are only about a dozen pits at work, with an insignificant output. Many of the deposits are far away from railways or from the Danube, a circumstance which complicates the problem of transportation. The net result is that imports of coal, and even of lignite, into Servia increase year by year, while the prices paid are high, too high in the authors' opinion.

The Morava coal-field, the only one that is described in this paper, lies in the district of Alexinatz, and extends over a belt of country some 13 miles in length. The State railway runs all along the western edge of the coal-field. The Coal-measures are of Tertiary age, and end abruptly against massive gneiss. The seams in this field have been worked for about 15 years: of the two principal seams, one is over 16 feet thick, and the other varies between 7 and 14 feet in thickness.

On the right bank of the Morava, on the road from Belgrade to Alexinatz, is the concession belonging to Mr. Appel. Here the strike of the seams is north and south, with a westerly dip of 22 degrees. The floor of the thickest seam is a very compact fine-grained sandstone, and the roof is a compact, laminated oil-shale, some 170 feet thick. This shale can be ignited with a match, and burns with a long flame, like that of beechwood. Experiments have shown that on distillation it yields 25 per cent. of paraffin; nevertheless no industrial use of it has been made so far. The sandstones themselves soon pass into paraffin-shales, and it appears probable that other coal-seams will be struck in these shales, overlying which is the valley-drift of the Morava. The coal is highly bituminous, breaks into large pieces, and sells in the northern provinces at £5 8s. per truck. Carriage from the pit-mouth to the railway-station costs 33s. per truck.

The Johannis colliery, near Alexinatz, is worked by a shaft 180 feet deep, properly tubbed, and provided with ascending and descending cages. The first level (100 feet below bank) runs northward, and is more than 600 feet long; the second level (70 feet below the first) follows the seam. The coal here is less compact than that previously described, is of a shiny black, very hard and clean, and costs at the railway-station: large, £4 per truck; small, £3 per truck; duff, £1 5s. to £2 per truck. The average selling price is 5s. 1d. per metric ton, and the costs amounting to 3s. 7d., the net profit works out at 1s. 6d. per metric ton. L. L. B.

SUBMARINE IRON-ORE DEPOSITS IN THE GULF OF FINLAND.

Magnetiska Undersökningar i Trakten af Jussarö. By A. F. Tigerstedt. *Fennia (Bulletin de la Société de Géographie de Finlande)*, 1899, *vol. xiv.*, *No.* 8, *pages* 1-19, *with* 5 *plates of maps.*

That portion of the Gulf of Finland in which the island of Jussarö is situated has been for many generations recognized as dangerous to navigators, on account of the aberrations of the compass set up by the rocks and hidden reefs. The magnetic survey recorded in this paper leads to the following conclusions:—

The above-mentioned aberrations of the compass are due to the existence of vast deposits of highly magnetic ores, striking east and west, beneath the sea-waves. Divers have brought up several samples of the ore, and it has been observed that the "upper poles" of the deposits always attract the northern end of the needle. It cannot be asserted that there is a combined magnetic effect produced by all the ore-deposits taken together, unless it be at a considerable distance from the magnetically anomalous area, and then only very much weakened. Within the anomalous area the northern end of the needle points in any direction, influenced solely by the lie of the nearest ore-pole.

The Segersten deposit, the most considerable of all, ranges along a sharp curve past the islands of Orrkobben, Stenlandet and Lerharu, for at least 2¼ miles, has an estimated thickness [breadth] of 80 or 100 feet, and goes down to a great depth. The Väster Gadden deposit is much more irregular, and indicates a less intense concentration of ore; it would appear, moreover, not to extend so much in depth. The vertical magnetic intensity is especially strong in the case of the Segersten deposit, amounting to four times the intensity of the horizontal component of the earth's magnetism. Moreover, in the course of the measurements, the horizontal magnetic intensity of the Segersten ore was found to be high enough, at a distance as great as 300 feet north of the nipping-out of the deposit, to counteract the influence of the earth's magnetism, the northern end of the needle in that area pointing on the whole southward.

The investigations made in regard to the iron-ore deposits on the island of Jussarö itself, deposits which were actively worked during the first half of this century, have shown that they are of very secondary importance compared with the submarine ore-body of Segersten. The practical outcome of these researches is that in the spring of 1898 a company was formed, with the avowed purpose of exploring more fully the Segersten deposit by means of borings. This exploration-work may be expected to throw light on the character of the ore and the possibility of mining it. L. L. B.

THE PEATS OF FINLAND.

Studien öfver Finlands Torfmossar och fossila Kvartär-flora. By GUNNAR ANDERSSON. *Fennia (Bulletin de la Société de Géographie de Finlande),* 1899, *vol. xv., No.* 3, *pages* 1-210, *with* 21 *figures in the text and* 4 *plates.*

The author defines peat, as it occurs in Finland, as consisting of plant-remains more or less decomposed, but with their structure in fair preservation, of very variable appearance and characteristics. The peat is divisible into two main categories:—

(1) Peat formed from vascular plants, such as the roots, stems, seeds, etc., of reeds, rushes, horsetails, ling, and so on (*Carex, Phragmites, Scirpus, Eriophorum, Calluna*); and

(2) Peat formed from mosses such as *Sphagnum, Amblystegium,* etc.

A description is given of the associated Quaternary sands, clays and coprolitic deposits (known as *Gyttja*). There is also a pseudo-peat, called *dytorf,* formed by the precipitation of humic salts and of iron and lime-salts from acidic waters: along the edges of this deposit, it is full of drifted remains of twigs, tree-trunks, etc.

With regard to the fossilization process which attends the formation of true peat, the author points out that where the cellulose of plants survives, this survival is probably due to impregnation with tannic acid. If the cell-walls of all plants had consisted of pure cellulose, hardly the faintest trace of them would be found fossil. In the Finland peat, so far as the recent flora is concerned, 63 per cent. of the known indigenous trees were found and 50 per cent. of the shrubs, but of the non-ligneous, herbaceous vegetation, apart from the aquatic plants, scarcely a specimen occurs.

It is by the formation of ligneous and suberous (cork) material that cell-walls become sufficiently tough to resist decomposition-processes under water. Silicification has something to do with the survival of the horsetails and a few of the mosses, but there is no example in Finland of the preservation of peat plants by calcification. Tannic acid plays a far more important part in the process of peat-formation than had been hitherto suspected.

A careful descriptive catalogue, with illustrative plates, is given of the various plant-remains found in the Finland peat; among the trees we notice species of birch, alder, ash, oak, pine, hazel, poplar, lime and elm. This exhaustive memoir concludes with an historical study of the Quaternary flora of the Duchy.

L. L. B.

MODE OF FORMATION, &c., OF THE ARGENTIFEROUS DEPOSITS OF KONGSBERG, NORWAY.

Ueber die Bildung des gediegenen Silbers, besonders des Kongsberger Silbers, durch Secundärprocesse aus Silberglanz und anderen Silbererzen, und ein Versuch zur Erklärung der Edelheit der Kongsberger Gänge an den Fahlbandkreuzen. By PROF. J. H. L. VOGT. *Zeitschrift für Praktische Geologie,* 1899, *pages* 113-123, *and* 177-181, *with* 10 *figures in the text.*

A whole series of observers, from Prof. G. Bischof onwards, have drawn attention to the fact that metallic silver may be got from the natural sulphide by the simple process of passing steam or hot air over that mineral, and the inference is obvious that the native silver found in such mines as those of

Kongsberg has been formed naturally by an analogous process. The author remarks, however, that many mining-engineers have hitherto shown themselves inclined to scepticism on this point.

Münster proved that from silver sulphide of compact structure, a similarly compact metallic silver is obtainable, whereas a porous sulphide yields the metal in form of threads, fibres, or moss. Prof. Liversedge has shown that moss-copper is produced by a reaction similar to that mentioned above, and Dr. Regnault has got metallic mercury from cinnabar in the same way. It is claimed that at Kongsberg the natural process can be followed step by step, and the remarkable illustrations which accompany this paper appear to bear out the author's contention. The rapidity with which the reaction takes place is beautifully shown by the little masses of sulphide clinging to the ends of the curling fibres of native silver. These fibres might well be termed 'plants' (to which they have a curious resemblance), growing on the surface of the sulphide, but not deeply rooted in it. The transformation into metal seems, in some cases, to spread gradually from a thin layer through a whole block of the sulphide, in such wise that blocks of native silver weighing nearly ¼ ton have been found at Kongsberg. Just as it is rare, however, to find these masses without some admixture of silver-glance, so is it equally rare at Kongsberg to come upon large masses of the sulphide that are not to a greater or less extent interpenetrated or encrusted by native silver. In those mines ruby silver-ore is comparatively rare, but the same phenomena of transformation have been observed in it as in the more abundant silver-glance. Moreover, it can be shown that some of the native silver of Kongsberg is not derived from the sulphides, but has crystallized direct out of a metalliferous solution. It occurs, for instance, in the clefts and joint-surfaces of the anthracite which is associated abundantly with those ore-deposits; and some of it, too, is combined with mercury in varying quantities, the amalgam containing from 4 to as much as 23·07 per cent. of mercury. Still, on the whole, it may be said that native silver in the form of crystals, as distinct from fibrous, hair- or moss-silver, plays a very subordinate part at Kongsberg.

The proportions of the annual output from the mines are variously estimated by different authorities, but, while citing these, the author comes to the conclusion that the true proportions are:—Native silver, 90 to 95 per cent of the total, and silver-glance, 10 to 5 per cent. of the total, the average annual production of the metal there being 160,750 ounces Troy.

The minerals which constitute the gangue of the Kongsberg veins are, in the order of their abundance:—Calcspar, fluorspar, quartz and anthracite. Heavy spar is common only in a few of the veins. Besides the remarkable frequency of anthracite, it may be noted that much of the calcspar contains inclusions of bitumen and coal. Apart from silver-glance, the most important ores in that locality are iron-pyrites, zinc-blende, galena, magnetic pyrites, chalcopyrite, with (occasionally) mispickel, cobalt-bloom, and a few still rarer ores. Indeed, with the exception of iron-pyrites, all the foregoing play so very trivial a *rôle* in the Kongsberg deposits that the mass of silver is greater than that of all the other heavy metals put together.

The succession in time of the Kongsberg minerals appears to have been as follows:—(1) quartz; (2) metalliferous sulphides, native silver, anthracite and the older calcspar; (3) fluorspar and heavy spar, with a little adularia and albite; and lastly (4), three or four generations of calcspar, a younger quartz and a younger iron-pyrites-formation, axinite, magnetic pyrites, and zeolites. These successive periods are not sharply defined, but melt one into the other. The formation of the silver-glance and the primary silver began at the end of the first quartz-generation, and then took place in the main simultaneously with the deposition of the anthracite, the older calcspar, and several of the sulphide ores. It continued in a lesser degree during the crystallization of the fluorspar and the younger generations of calcspar. The reduction of the silver-glance to metallic silver took place earlier than the formation of the main mass of calcspar and fluorspar, magnetic pyrites, and younger iron-pyrites, probably almost immediately after the silver-glance had crystallized out. It may be remarked parenthetically that later on some of the silver was reconverted into silver-glance.

On the whole, the author considers that the deposits which show the greatest similarity to those of Kongsberg are the ore-bodies of Andreasberg in the Harz, and he recapitulates their identical characteristics. He then draws attention to the fact that, at Kongsberg, especially rich ore is struck at the points of intersection of the fahlbands. It is plain that these fahlbands have had some extraordinary influence on the solutions percolating through the vein-fissures. Remembering that these solutions were rich in carbonic acid, the explanation appears to be that the pyrites in the fahlbands was attacked by them, and the hydrogen sulphide thus set free precipitated the silver from solution in the form of sulphide. The association of anthracite or of bituminiferous calcspar with the richer portions of the veins is so striking that the Kongsberg miners assert that no silver-ore is to be found unaccompanied by carbonaceous material.

Turning then to the general geology of the district, the author describes among the principal rocks ophitic olivine-gabbro (hyperite), and grey gneiss or "squeezed granite" (of which chemical analyses are tabulated), in places pyritiferous. The area was in former ages the scene of numerous and vast igneous eruptions, and the formation of the metalliferous deposits is to be regarded as one of the later effects of vulcanicity. The ores are not the product of lateral secretion, nor were they brought in from above, but they came up from below. It is stated, by the way, that the greatest vertical depth so far reached in the Kongsberg mines is 2,300 feet; three mines are between 1,650 and 2,300 feet deep; and nine are from 970 to 1,650 feet deep.

The paper concludes with references to occurrences of native gold, which have apparently originated in much the same way as the native silver of Kongsberg, and there is a short appendix dealing with the amount of pyrites in the fahlbands. L. L. B.

PYRITES-MINES OF SOUTHERN SPAIN AND PORTUGAL.

Das Huelva-Kiesfeld in Süd-Spanien und dem angrenzenden Theile von Portugal. By PROF. J. H. L. VOGT. *Zeitschrift für Praktische Geologie,* 1899, *pages* 241-254, *with a map and* 5 *illustrations in the text.*

The numerous deposits of pyrites in the Huelva district of Southern Spain lie within a zone, 80 miles (130 kilometres) long, running from east to west, and about 12 miles (20 kilometres) broad. The western end of this zone crosses the Portuguese frontier at the important mine of San Domingo, which lies a few miles west of that frontier. All the other important mines, Rio Tinto, Tharsis, La Zarsa, Lagunazo, Aguas Tenidas, Sotiel, San Miguel, etc., lie within the kingdom of Spain. Huelva is the port for the whole central and eastern portion of the ore-fields, lying 52 miles (83 kilometres) by rail from Rio Tinto, 42 miles (67 kilometres) from Aguas Tenidas, and 28 miles (45 kilometres) from the old main mine of Tharsis. The navigable river Guadiana affords a means of transport for the western mines, namely, for those of San Domingo, and for the two mines owned by the Bede Metal Company. Only the pyrites-deposits will be considered here, and not the deposits of manganese-ore, upon which Prof. Klockmann is preparing a memoir.

Geology.—The coastal area on the Atlantic Ocean between Cadiz and the Portuguese frontier consists of Tertiary and Quaternary deposits. Somewhat further northward, on either side of the long zone of pyrites-deposits, there occurs a series of locally metamorphosed slates, in which the existence of Silurian and Carboniferous fossils has been proved, and these slates are traversed by numerous outbursts of porphyry. Further north still, the western portion of the Sierra Morena consists mainly of Cambrian and Azoic slates. Within the east-and-west zone, in which the pyrites-deposits occur, fossils have been found in several localities, which partly belong to the Silurian, partly to the Carboniferous age (*Posidonomya Becheri*, *Goniatites sphæricus*, etc.). On account of these fossil discoveries, the number of which, however, is but small, and further on account of the petrographic character of the rocks, Prof. Gonzalo y Tarin has distinguished in this district the two formations of Silurian and Carboniferous Culm. Devonian fossils have not been found here, and according to the above-named author, Devonian strata are supposed to be wanting. This conclusion does not, however, appear to the author to be clearly proved, as the fossil discoveries are but few and are scattered over a very wide area. The slates have but few distinguishing petrographical characteristics, and their appearance cannot therefore be used as the basis of a detailed subdivision. It is consequently quite possible that the view of Prof. Klockmann that there is a continuous series of Silurian, Devonian and Carboniferous may prove to be correct. The slates have often been subjected to dynamo-metamorphosism, and are very frequently phyllitic. The strike is generally to the east, and the dip a fairly steep one. Transverse slatey cleavage is often noticeable.

Within the pyritic zone occur a considerable number of eruptive dykes of porphyries, with a highly variable degree of acidity, the silica ranging from 70 to 40 per cent. Quartz-porphyry is very frequent. Diabase-porphyry also occurs in various intermediate stages. It may be said that there is here a fairly continuous series of highly differentiated eruptive rocks in all stages, from the basic to the acid extremities. Prof. Gonzalo y Tarin concludes that these eruptive rocks are intrusive, while Prof. Klockmann, on the other hand, maintains that they are bedded, forming sheets, everywhere conformable with the slates, and are even in places accompanied by deposits of tuff. The occurrence of porphyries in the Huelva district does not, however, admit of the definite conclusion that they are interstratified, as maintained by Prof. Klockmann. Further, it is by no means certain that the rocks which he considers to be tuffs and ashes are really of this nature. They may quite well be more recent breccias. The author therefore concludes that the eruptive rocks of this region are in fact dykes of more recent age, and more particularly occur in the form of bedded dykes.

The coastal strip along the Atlantic, between Cadiz and the Portuguese frontier, is mantled over by Tertiary and Quaternary sedimentaries. The attempt by previous observers to map out the pyrites-deposits in three parallel belts is not borne out by the author's studies. Within the before-mentioned zone, occur a large number of important deposits of pyrites, lenticular in shape, some of which are of enormous size, occasionally over 500 feet (150 metres) in width. The lenticular form is evident not only in the horizontal, but in the vertical direction, so that the pyrites often pinches in depth, in some cases at comparatively shallow depths. In most cases, these lenses are parallel to the surrounding slates and porphyritic rocks, and they occur strikingly often in intimate relation with the latter. Thus the porphyry very frequently forms one wall of the deposit, sometimes the hanging-wall and sometimes the foot-wall. It occasionally happens that deposits of pyrites, for example No. 2 deposit of Rio Tinto, lie between two bedded flows of porphyry which are only separated from each other by slates a few feet thick. In marked contradistinction to the well-known often strikingly clearly striated pyrites of Rammelsberg, the Huelva pyrites is distinguished by its perfectly massive structure without any signs of striation or bedding. As previously remarked, the South Spanish pyrites deposits are remarkably similar to many other European deposits, such as those of Röros, Vigsnäs, and Sulitelma in Norway, Rammelsberg in the Harz, Schmöllnitz in Hungary, and Agordo in Italy, so much so that it may be concluded with some degree of safety that their formation must have taken place under similar conditions. Therefore the author agrees with Prof. Gonzalo y Tarin that the Huelva pyrites, as we now find it, is a direct result of the porphyry-injections which took place after the crumpling and folding of the stratified rocks.

Tables of dimensions and illustrative sections are given, to show the extreme irregularity of the lenticles, as well as their enormous thickness and their still greater length. The author calculates that in its upper portions the Rio Tinto deposit, for every foot in depth, yields as much pyrites as Gellivaara does iron-ore, while the moderately extensive deposits of San Domingo, on the Portuguese side of the frontier, and Aguas Tenidas, are comparable as to yield of ore with various German and Swedish mines.

An examination of the area of the various deposits leads to the conclusion that the total quantity of pyrites originally present in all these deposits must have been approximately as follows:—Rio Tinto, from 175,000,000 to 200,000,000 tons; Tharsis, say, 30,000,000 to 35,000,000 tons; and San Domingo, from 15,000,000 to 20,000,000 tons. Of the other deposits, there is probably none that exceeds 10,000,000 tons. The majority may vary from a few up to 5,000,000 tons. Altogether, then, it may be assumed that the original quantities of pyrites present in the workable Huelva deposits down to a depth of 1,000 to 1,300 feet (300 to 400 metres) should be calculated at least at 250,000,000, and at the utmost at 300,000,000 or 400,000,000 tons. In these figures many poor impregnations of pyrites, which are only of geological interest, have not been included.

The calculations made in past years as to the mass of workable ore available were vitiated by the neglect of the fact that the Huelva deposits are lenticular in the vertical plane as well as in the horizontal. Making the necessary deductions, it is estimated that the remaining ore available on the Rio Tinto property is 135,000,000 tons, about one-half of which (in the author's view) will prove practically barren of copper. He foresees, in consequence of the diminished value of the ore and the increased cost of working which follow the same ratio as the increase in depth, that the Rio Tinto field may be worked out within the next 50 years, if not earlier. The original Tharsis mines will hardly hold out so long, but the company has been careful to purchase new properties. The output of the San Domingo mine is already on the down grade, and this seems to be the case also with Aguas Tenidas. It is estimated that the total amount of pyrites worked out of the Huelva field since 1850, when modern mining operations may be said to have begun, until the end of 1896, is roughly 63,000,000 tons. The Romans appear to have got out no less than 30,000,000 tons in their time. Now, although the amount of less than 100,000,000 tons so taken away represents in mass only a third or a quarter of the available ore, it is really the most valuable portion that has gone, considering its high percentage of copper and its low cost of working.

Seven chemical analyses are tabulated—three of the Rio Tinto, two of the Tharsis, and two of the San Domingo ores, wherein the percentages vary as follows:—

	Minimum percentage.	Maximum percentage.
Sulphur, S	44·60	49·60
Iron, Fe	38·70	45·55
Copper, Cu	2·26	5·81
Zinc, Zn	trace	0·35
Lead, Pb	0·52	1·52
Arsenic, As	0·21	0·47
Magnesia, MgO	trace	0 13
Lime, CaO	0·14	0·90
Insoluble matter (Silica, SiO_2)	0·73	11·10
Oxygen (in oxide of iron, O_2)	0·15	1·07
Water, H_2O	0·05	0·95

In addition to these constituents, there is often a trifling proportion of silver (0·0025 to 0·0040 per cent.) and gold (in quantities equal to about $\frac{1}{100}$ of the silver) with traces of antimony, bismuth, nickel, cobalt, tellurium, selenium, thallium, etc.

The ores are predominantly iron pyrites (FeS_2), with a relatively small admixture of chalcopyrite, but in the Aguas Tenidas mine copper is all but absent, and the ore there is, moreover, free from arsenic. The secular weathering of the surface of the land in a practically sub-tropical climate accounts for the persistence of a deep ferruginous gossan, averaging 35 feet in thickness, but sometimes as much as 160 feet thick. It consists mainly of oxides and hydrates of iron, yielding 50 to 55 per cent. of the metal, with a little sulphur and an infinitesimal proportion of arsenic, but the copper has been completely oxidized and dissolved out of it. In one of the Rio Tinto mines, the junction between the gossan and the fresh pyrites is marked by an earthy porous layer, several inches thick, rich in silver and gold, to an average value of £7 10s. per ton. Evidently the formation of this earthy layer is connected with the processes of oxidation which went on in the gossan.

It appears to be a definite law, as shown by an examination of the various deposits, that the copper contents of the pyrites diminishes in depth. This may be specially well illustrated by a section of the San Domingo mine, where the content of copper has gone down from 4·5 per cent. between 65 and 130 feet (20 and 40 metres) to about 1 per cent. at 460 feet (140 metres). Similar results are noticeable at Dionisio, near Rio Tinto.

With regard to the future of the Huelva district, it may be noticed that since about 1890 the Huelva copper-production has remained practically constant, whilst the world's production has increased enormously. In 1880, the Huelva district accounted for between 25 and 31 per cent. of the world's copper-production, whilst in 1896 it was only producing 14 per cent., and these mines have, therefore, had to yield their leading position in the copper market to Montana and Michigan. It seems tolerably certain that, as to the production of copper, the Huelva district is now at its highest point. It can only maintain its production at its present high rate for a few more decades, and then will commence to decline. This is due to the facts already pointed out: namely, that firstly the deposits narrow going downwards; secondly, that the pyrites becomes poor in copper in depth; and, thirdly, that the cost of mining must increase considerably as depth is attained. In most of the mines, the greater portion of the upper zone, which is rich in copper, has been got at a comparatively low cost of production, and many mines are therefore rapidly approaching the more costly and, at the same time, poorer portions of the deposit. At Rio Tinto, the position will, however, be more favourable for, say, the next 50 years. However, even here a marked increase in the amount of copper-production is not to be expected. It is, therefore, noticeable that whilst the copper production of Huelva has reached its maximum, the production of export pyrites is still on the increase. This is due largely to the recent process introduced in San Domingo and in Tharsis, in which the poorer pyrites is not roasted to extract the copper. The sulphur therefore remains unaltered in the pyrites, and after the copper-extraction has been completed, or, say, after 6 or 8 years, the ore can be shipped as pyrites poor in copper.

The author concludes that the impression he obtained from his journey in the Huelva district was that the other pyrites-mines of Europe, and especially those of Norway, were not likely to be in a worse position than they had been up to the present in respect of the competing influence of Huelva. Huelva would only be able to maintain its present colossal production of about 3,000,000 tons per annum for a limited number of years, after which it will be more than ever necessary to fall back upon the remaining deposits of Europe. The Huelva districts, most of the mines of which are in the hands of English capitalists, afford an extreme example of the Anglo-American method of working, *i.e.*, extraordinarily "intensive" scale of operations in a limited period; the Germano-Scandinavian principle, namely, a moderate speed of production which can be maintained for centuries, is to be preferred from general, national, and economic considerations. L. L. B. & H. L.

MINERAL RESOURCES OF SHANTUNG, CHINA.

Ueber eine Bergmännische Forschungsreise in der Provinz Schantung. *By* A. Dieseldorff. *Zeitschrift für Praktische Geologie*, 1899, *pages* 206-209.

This paper gives in brief the results of a prospecting journey undertaken in the course of 1898 by Dr. Buchrücker, a German mining engineer.

Shantung is separated from the Central Asian mountain-system that terminates northward in the Hwai range by a wide fertile plain, which represents probably an old fault-depression filled up by detritus washed down from the hills and alluvial gravels, etc., deposited by the Hwang Ho. Shantung, on the east of this plain, is very similar in orographic and geological structure to the provinces of Shansi and Honan on the west of it. In all alike, the fundamental rocks are crystalline schists, gneisses and granites, overlain by Cambrian and Silurian strata. These, in turn, are covered by a vast stretch of Carboniferous rocks, especially productive Coal-measures. The Rothliegende which, in regular succession, comes on the top of the Carboniferous, overlaps on to the Silurian, and no strata of Old Red Sandstone age have so far been discovered in Shantung.

The coal-fields, excepting that of Póshan, are worked by means of shafts. These average only 65 feet in depth, as the general water-level of the country is very soon reached. Mining only goes on for 6 to 8 months in the year, and is completely suspended at harvest-time and during the rainy season. Meanwhile the water rises in the pits, and it generally takes 2 months to drain them again. The methods of drainage, haulage, and of mining generally are incredibly primitive. The shifts work for 24 hours at a stretch, and the Chinese pitman's maximum wage is barely 6d a day. The coal is of a meagre, anthracitic character, and yields much ash: coke is produced on a small scale. There is reason to believe that, with deeper shafts and more extended exploration of the vast area of Coal-measures, more highly bituminous seams will be found.

The author notes that the Tsi-nan-fu basin, enumerated by Richthofen among the Shantung coal-fields, has been since recognized as of small importance, and the workings in it have been abandoned.

Intimately associated with the coal of I-chau-fu are huge lenticles of hæmatite, recalling a similar occurrence in Saxony. They were mentioned by Richthofen, but he does not appear to have realized how great a mass of them is present. The ore is of excellent quality, it can be got in opencast workings. and the close proximity of the sea-coast suggests facilities of transport.

The Shantung rivers carry gold, but the present results of the washings are not such as to encourage any attempt to work the alluvia on the European system, although the Chinaman contrives to make a living out of them. Better results, however, are obtained from the laterite, near its line of junction with fresh, undecomposed rocks in the east and south-west of the province: the rocks are granite and gneiss, traversed by grey quartz-veins.

Native copper, in lumps as big as a man's fist, occurs north of Mongyin; and silver and fahlores north-east of that locality, while galena is recorded from Fei-hsien. An extensive deposit of workable mica is found several days' journey from Kiowchau Bay. The slabs are about 20 inches in diameter, 1 inch or more thick, and beautifully transparent: the matrix is "giant granite." Missionary Williamson's report of the existence of diamonds was long ignored or disbelieved, but they are now known to occur on the right bank of the I-ho, where the Chinese often plough them up in the fields after heavy rain. The stones are mostly colourless octahedra, but some are yellow or have a greenish tinge: the natives do not attempt to cut them or use them for personal adornment, but they bore holes for wiring porcelain together with the rough diamond, and they use the stones as currency or pawn them.

L. L. B.

TIN-DEPOSITS ON THE RIVER ONAN, EASTERN SIBERIA.

Gisements de Minerais d'Etain sur la Rivière Onone. *By* J. A. Korzoukhine. *Bulletin de la Société des Ingénieurs des Mines, St. Petersburg,* 1899, *No.* 4, *pages* 22-35.

With the exception of Pitkäranta, where the production of tin is insignificant, the only Russian deposits of cassiterite are in the territory of the Transbaikal, on the river Onan and its affluents. The Onan joins with the Ingoda to form the Shilka, which in its turn unites with the Argouni to form the river Amur, which empties into the Pacific Ocean.

Up to the present, the existence of cassiterite on the Onan has been recognised at the four following points:—(1) Near the village of Olovianny Rudnik, on the left bank of the Onan. (2) Opposite this same village on the right bank of the Onan, in the valley of the Little Kulinda, an affluent of the Onan. (3) Near the village of Nizhni Sharanaï, on the right bank of the Onan. (4) Near the village of Zavitinskoe, in the valley of the Sludianka, on the right bank of the Ingoda, at 10 versts (6 miles) above the affluents.

The geology of the country is very uniform throughout the whole region in which these deposits occur. The predominant rocks are granite and clay-slates. It has been recognized that cassiterite exists for a distance of more than 70 miles along the Onan, and this fact would point to the existence of a large tin-bearing region, where there is every reason to suppose that new deposits of this mineral may yet be discovered.

From the information obtained, it appears that in the numerous gold-placers which exist here, whenever gold is washed a quantity of cassiterite is also obtained, which confirms amply the above supposition that a large region rich in tin must exist.

Up to the present, the country has scarcely been explored, for the population is exceedingly scattered and in a very rudimentary state of civilization. The native Buriats know the country better than any one else, but they are careful to conceal the knowledge of any deposits which they discover, for fear of finding themselves driven out from the ground which they are working. In their justification, they are fond of reminding us that they never received any reward for having pointed out the existence of deposits of tinstone, but that, on the contrary, whenever they have done so, they have been recompensed by having to move from their own lands and shift their villages, leaving to others the advantage of working the deposits.

The first deposits of cassiterite on the river Onan were discovered in 1811. The Governor-General of Irkutsk informed the Minister of Finance about them, writing to the effect that the indigenous Buriat tribes encamped at the mouth of the Tsotsul, an affluent of the Onan, had discovered and handed to the chief, Halzan Mordaïew, a mineral from which tin had been extracted. According to an analysis made by a Mr. Kharinsky, the mineral contained from 1·30 dolia to 1·50 dolia of fine metal per pud. The Governor-General sent the above Kharinsky into the district where the ore had been found. Specimens were sent to St. Petersburg, which yielded per pud of ore 6 pounds 50 dolia of very ductile tin. Experiments showed that the metal was pure and of a high quality.

The same year, the manager of the Nerchinsk works reported to the Minister of Finance that having been informed by a peasant named Litvintzew that the natives were working mineral deposits on the river Onan, he sent a mining engineer into this country, who reported upon his return that he had found many ancient workings, and that, judging by their number, the natives must have been occupied in this industry for a very long time.

In addition to the deposits pointed out by the natives, others were discovered in their neighbourhood, viz:—(1) The deposits of Kulinda, discovered in 1813-14, which were worked to 1818. (2) The deposits of Sharanaï, discovered in 1815, which were only surface-workings, and abandoned in 1820. (3) The deposits of Zavitinskoe, discovered in 1817, were abandoned in 1821 as being too poor.

The deposits which had been pointed out by the Buriats, and which received the official denomination of primitive deposits, were, and still remain, the centre of the tin-production. For reasons to be given below, these deposits were abandoned in 1852, and no further attention was paid to them until they were revisited by the author in 1898.

These so-called primitive deposits are situated 1 or 2 miles from the village of Olovianny, by the Onan, in a deep valley formed on the north side by the Rudnichnaïa, and on the south by Mount Slantsevaïa. The general direction of the valley is at right-angles to the Onan. The rocks that outcrop are grey argillaceous schists, very compact. Near the summits of the above-named hills, these schists come to the surface, whilst in the centre of the valley they are overlain by a deposit of alluvium from 10 to 14 feet (1½ to 2 sagenes) thick. Mr. A. P. Gherassimow ranks these schists among the grits and schists which he has examined on the Ingoda and Shilka, and places them temporarily in the upper series of the pre-Cambrian formation. These schists rest, as is seen in the banks of the Onan, upon granite, and are traversed by a large number of veins of milky-white quartz, running about north-north-west, and dipping west-south-west at an angle from 60 to 80 degrees. The general direction of these veins is very regular, although they present here and there curves and deviations, as is the case with all veins. Their thickness is between 28 to 32 inches (0·7 to 0·8 metre) and 3 to 6 inches (0·09 to 0·15 metre). Most of these veins show in their walls chiefly mica (pale yellow muscovite). Sometimes, however, they consist of greisen. The cassiterite is found both in the walls of the veins and in the quartz itself.

Although this deposit had been known since the commencement of the century, it could not be said that it had been either exploited or properly explored. It was true that after its discovery it was proposed to work it on a considerable scale, but this intention was never executed. The work done up to the year 1834 was irregular, and neither followed the veins nor cut across them. These facts are not astonishing, seeing that the work was not under the direction of officers of the Department of Mines, but was carried on by foremen, from whom no knowledge of the mineral deposits was to be expected. It is therefore not difficult to understand why so little attention was paid to these workings. Whatever work was commenced seriously, was abandoned before the year 1830, and any work done after that was not done on any systematic plan. The writer must, however, add that these later workings were conducted more regularly than those which were executed in accordance with the plans officially approved. It must be noted that the greater portion of the tin and tin-ore produced for the Crown, came from the alluvial deposits which occur in the middle portion of the deep valley.

As regards the matrix, properly speaking (the veins of quartz in which the cassiterite is desseminated), it had been very little worked; it had only been cut in surface-workings opened at some of the points of outcrop, especially in the eastern side of the southern face of Mount Rudnichnaïa. All the work done has been irregular, and on account of the narrowness of the veins such a depth was soon reached that it was difficult to advance any further. It must be borne in mind that all these works were executed with picks and wedges. The amount of work done was therefore but little, the quartz being very hard. Attempts were subsequently made to work by fire-setting. Seeing that the wood used as fuel had to be floated down from the Upper Onan, the adoption of this system could hardly be looked upon as reasonable. A shaft was sunk on the bank of the river, water from which was raised by means of a noria worked by horses, and was then used for washing the ore. The ore washed by this process naturally became highly expensive.

After the year 1837, the work was organized on the basis that each workman was bound to produce somehow and from somewhere a ½ pud of pure ore. This regulation naturally caused the *débris* of the ancient workings to be washed over again, and under these conditions the production of tin became so costly that after the year 1852 the Governor stopped it altogether, These 40 years of working in the only tin-deposits existing in the Russian Empire have not been productive of any advantage, but on the contrary have been distinctly injurious. The abandonment of these deposits, although it was due to the fact that they were worked badly, has been interpreted as meaning that the deposits themselves were not sufficiently productive. It is difficult to understand how this opinion has arisen, although it is true that but little has been written on the subject of these tin-mines. The most detailed and scientific is a report by Mr. M. J. Kovriguine, an officer of the Department of Mines, appearing in the *Journal des Mines* for 1830, under the form of a report concerning his explorations in 1829. Mr. Kovriguine's opinion was, upon the whole, favourable, but it must be remembered that he, being a stranger, laid great weight upon what the natives of the country told him. In his report he stated that the veins of quartz containing cassiterite pinched out rapidly both in strike and in depth, and as greater depth was reached, the quantity of cassiterite diminished. It would seem that this utterance of Mr. Kovriguine had caused the unfavourable opinion which had been formed of these deposits. If his view were correct, it was certain that the working of these deposits would be very difficult.

The author's opinion, formed from the first time he visited the mines, was that there can be no question as to the veins not being sufficiently extensive. The workings show that the same vein has been cut in many different places, apparently wherever it cropped out on the surface, and that some of these points were a considerable distance from each other on the two hills already named. There was, therefore, no question but that the veins continued very satisfactorily in strike. The author had made certain explorations, and especially on a vein situated to the east of the aquamarine cutting in the upper portion of Mount Rudnichaïa, which was especially convenient of access. This vein having been worked more than the others, the author considered that if he could determine the cause which led to its abandonment he might be able to form conclusions as to the reason of the general abandonment of all the deposits. He was able to determine that this vein continued in depth, did not diminish in thickness, and even showed some slight tendency to widen, the greatest depth reached being 40 feet (5½ sagenes).

Up to the present time, it was impossible to say how many veins there really were, seeing how little work had been done. The alluvial deposits that existed in the centre of the valley everywhere contained tin. They had been worked on behalf of the Crown, but the workings had never reached bed-rock.

Deposits on the river Kulinda and near the village of Sharanaïskaïa differ essentially from these so-called primitive deposits. In the latter place, veins of granite are seen, penetrating argillaceous schists. The granite is tin-bearing, but the quantity of tin which it contains is unknown.

According to statistics contained in the archives, one pud of rock contained 2½ pounds of tin, or, say, 6½ per cent. There was no reason to believe that this figure was an exaggeration, but it was probably less than the truth.

As regards the working conditions of the tin-deposits, they may be looked upon as highly favourable. No great ditches or works will be required to bring the water on to the spot. The geographical position is also as favourable as it possibly could be. A railway is being constructed which will pass within about ¾ mile of the deposit below the Onan, where the Onan station is being built. This line will be a section of the Russian-Manchurian railway. It will start from the station of Kaidalovaïa (70 miles from the town of Chita), where it crosses the Ingoda, then runs along the bank of the Mogoïtoni, crosses the valley of the River Aga, passes at a distance of about 5 miles from the copper-deposits, of which something will be said below, and at 75 miles from Kaïdalovaïa runs close to the deposit of tin-ore. After having crossed the Onan at this point, the line runs along the river Turga, enters the deep valley of Tsunguruk, passes near the Hara-Nor lakes at a distance of from 6 to 8 miles from wolframite-deposits, which will be mentioned below; the line then crosses the river Onan-Borza, and after crossing the Nerchinsk mountains, enters the Chinese frontier near the Mutny stream.

This railway is of enormous importance for the tin-deposits; without mentioning that it facilitates communications with Chita, Irkutsk, and European Russia, this same railway will allow the tin to be carried to the Pacific Ocean, and will thus put these deposits on an equality with those of China, the Malay Peninsula, and islands of the Malay Archipelago.

The river Onan, beside which these deposits are situated, is also an important factor, as it is capable of furnishing water and hydraulic power, and, moreover, could yield large quantities of timber, the upper portion of the river being very densely wooded.

Ten miles north-east from the tin deposit, in a chain of mountains bordering the river basin of the Aga, a deposit of copper is situated in the deep valley of Mount Chuchi, which was worked between the years 1830-40, and known as the Aga copper-mines. There is scarcely any information about this deposit, even in the archives of the Nerchinsk works. As far as regards the natives, they remember that this deposit was worked intermittently, and they do not know the reason why it was abandoned. The only remains of the ancient workings are the small shaft, which has fallen in, a drift, and some unimportant surface-workings. The geological structure of this region is in general similar to that characterizing the stanniferous region, with this difference, that the argillaceous schists are principally met with at the mouth of the valley, whilst in the upper portion they become quartzose and horny in structure. Between these schists are beds of sandy and calcareous rocks, containing copper compounds disseminated through them. Up to the present, the copper has only been met with in the oxidized state, but it is probable that in depth sulphide-ores will appear. The main vein is very wide, 7 to 10 feet (1 to 1½ sagenes) and more. The quantity of copper contained in the ore appears to be 7 per cent. Further explorations are urgently required.

The wolfram-deposit is situated in the Adun-Chilon mountain-range, on Mount Shirlow, where famous mines of topaz, beryl, and aquamarine were worked in the eighteenth century. This mountain is traversed in many directions by veinlets of rock with veins of topaz, which consists of fine grains of crystallized quartz, in which, in addition to the quartz-crystals, there are small crystals of topaz, molybdenite, arsenical-pyrites and iron-ochre. In this vein, the crystals of precious stones occur which made the reputation of the Adun-Chillon range. In some poor descriptions which exist of the mines it is said that large quantities of wolfram occur in these topaz-veins. All the ancient workings have fallen in to such an extent that it is impossible to enter them without a great deal of fresh work. The author has therefore only been able to examine the ancient spoil-heaps, and found that the chief of these contained large quantities of the purest wolfram, analysis having yielded up to 70 per cent.

H. L.

II.—BAROMETER, THERMOMETER, ETC., READINGS FOR THE YEAR 1898.

BY M. WALTON BROWN.

The barometer, thermometer, etc., readings have been supplied by permission of the authorities of Glasgow and Kew Observatories, and give some idea of the variations of atmospheric temperature and pressure in the intervening districts in which mining operations are chiefly carried on in this country.

The barometer at Kew is 34 feet, and at Glasgow is 180 feet, above sea-level. The barometer readings at Glasgow have been reduced to 32 feet above sea-level, by the addition of 0·150 inch to each reading, and the barometrical readings at both observatories are reduced to 32° Fahr.

The statistics of fatal explosions in collieries are obtained from the annual reports of H.M. Inspectors of Mines, and are also printed upon the diagrams (Plates XXXIII. and XXXIV.) recording the meteorological observations.

TABLE I.—SUMMARY OF EXPLOSIONS OF FIRE-DAMP OR COAL-DUST DURING 1898, IN THE SEVERAL MINES-INSPECTION DISTRICTS.

Mines-Inspection Districts.	Fatal Accidents.			Non-fatal Accidents.	
	No.	Deaths.	Injured.	No.	Injured.
Durham	1	2	3	*6	6
Ireland	1	3	1	*0	0
Liverpool	0	0	0	5	6
Manchester	0	0	0	2	2
Midland	0	0	0	4	4
Newcastle-upon-Tyne ...	1	1	3	10	14
Scotland, East	1	3	1	28	34
Do. West	5	14	11	41	60
South Wales	0	0	0	32	44
South-Western	0	0	0	4	5
Staffordshire, North ...	0	0	0	2	2
Do. South ...	1	1	1	7	15
Yorkshire	2	3	2	7	9
Totals	12	27	22	*148	201

* These figures do not agree with those recorded in *Mines and Quarries: General Report and Statistics for* 1898, Part I., page 28

TABLE II.—LIST OF FATAL EXPLOSIONS OF FIRE-DAMP OR COAL-DUST IN COLLIERIES DURING 1898, IN THE SEVERAL MINES-INSPECTION DISTRICTS.

1898.		Colliery.	Mines-Inspection Districts.	Deaths.	No. of Persons Injured.
Jan.	28, 5·15 p.m.	Drumpeller (Nos. 3 and 4 Pits)	Scotland, West	4	0
Mar.	5, 10·0 a.m.	Whinney Moor	Yorkshire	1	0
„	31, 8·20 „	Kinneil	Scotland, East	3	1
Aug.	3, 8·30 „	Millfield	Staffordshire, South	1	1
„	17, 12·30 p.m.	Rosehall	Scotland, West	1	1
„	21, 5·0 „	St. Helens	Durham	2	3
Sept.	6, 11·30 a.m.	Greasbro'	Yorkshire	2	2
„	9, 2·30 p.m.	Ayr	Scotland, West	7	6
„	9, 1·0 „	Thankerton	Do.	1	0
„	29, 1·0 „	Annagher (No. 5)	Ireland	3	1
Oct.	25, 4·40 „	Nethercroy	Scotland, West	1	4
Nov.	3, 1·0 a.m.	South Elswick	Newcastle-upon-Tyne	1	3
			Totals	27	22

TABLE III.—LIST OF NON-FATAL EXPLOSIONS OF FIRE-DAMP OR COAL-DUST IN COLLIERIES DURING 1898, IN THE SEVERAL MINES-INSPECTION DISTRICTS.

1898.		Colliery.	Mines-Inspection Districts.	No. of Persons Injured.
Jan.	2, 1·40 p.m.	Thankerton	Scotland, West	2
„	4, 9·0 „	Douglas Bank	Liverpool	1
„	7, 8·0 a.m.	Lanemark	Scotland, West	1
„	7, 10·30 „	Fishley (No. 4)	Staffordshire, South	2
„	8, 6·10 „	Balquhatstone	Scotland, East	1
„	10, 11·0 p.m.	Whitehill	Scotland, West	1
„	11, 12·30 „	South Rhondda	South Wales	2
„	19, 7·30 a.m.	Waunceirch	Do.	1
„	20, 11·50 „	High-house	Scotland, West	2
„	24, 6·30 p.m.	Dumbreck	Do.	1
„	25, 3·0 a.m.	Clydach Merthyr	South Wales	2
„	26, 10·0 „	Deans (Oil-shale)	Scotland, East	1
„	29, 7·30 „	Golden Vein, Bryn	South Wales	2
Feb.	2, 5·0 p.m.	Varteg Hill	South Western	2
„	5, 3·0 a.m.	Pemberton	South Wales	1
„	15, 1·30 p.m.	Coppy Hall	Staffordshire, South	3
„	18, 7·30 a.m.	Jordan	Yorkshire	3
„	18, 9·15 p.m.	Phœnix	Liverpool	1
„	21, 7·30 a.m.	Madeley Wood (Blests Hill clay pit)	Staffordshire, North	1
Mar.	1, 6·0 „	Dalquharran	Scotland, West	2
„	4, 10·25 „	Shilbottle	Newcastle-upon-Tyne	2
„	5, 6·30 „	Peel	Midland	1
„	5, 9·30 „	Cornsilloch	Scotland, East	1
„	8, 9·30 p.m.	Meiklehill	Scotland, West	2
„	12, 3·0 a.m.	Blaendare Slope	South Western	1
„	12, 7·0 „	Glengarnock	Scotland, West	2
„	16, 6·20 „	Foxfield	Staffordshire, North	1
„	16, 9·30 p.m.	Motherwell	Scotland, East	3
„	17, 12·0 noon	Souterhouse	Scotland, West	1
„	18, 1·0 p.m.	Lanemark	Do.	3
„	18, 10·30 „	Newcastle	Midland	1

TABLE III.—*Continued.*

1898.	Colliery.	Mines Inspection Districts.	No. of Persons Injured.
Mar. 21, 6·30 a.m.	Tanfield Lea	Newcastle-upon-Tyne	1
„ 21, 11·30 „	South Rhondda	South Wales	1
„ 22, 7·0 p.m.	North Skelton	Durham	1
„ 28, 7·45 a.m.	Rankinston	Scotland, West	2
April 1, 8·0 „	Haughhead	Do.	1
„ 2, 6·45 „	Cornsilloch	Scotland, East	1
„ 2, 7·0 „	Lanemark	Scotland, West	1
„ 6, 2·0 p.m.	Trowell Moor	Midland	1
„ 11, 5·0 a.m.	Fergushill	Scotland, West	1
„ 15, 10·40 p.m.	Deans (Oil-shale)	Scotland, East	1
„ 19, 11·0 a.m.	Cornsilloch	Do.	1
„ 19, 5·0 p.m.	Gorseinon	South Wales	2
„ 19, 7·0 „	Holywell, Halkyn Tunnel	Liverpool	1
„ 21, 9·10 a.m.	Bedlington (A)	Newcastle-upon-Tyne	1
„ 26, 4·0 p.m.	Holmes (Oil-shale)	Scotland, East	1
„ 28, 8·0 a.m.	Auchenharvie	Scotland, West	5
„ 29, 2·0 „	Tannochside	Do.	2
May 2, 9·45 p.m.	Byers Green	Durham	1
„ 5, 6·15 a.m.	Harrington (No. 9)	Newcastle-upon-Tyne	2
„ 5, 12·30 p.m.	Aldridge	Staffordshire, South	1
„ 6, 6·0 „	Kenmuirhill	Scotland, West	1
„ 7, 1·30 „	Dechmont	Do.	1
„ 10, 3·0 a.m.	Ravensworth (Shop)	Newcastle-upon-Tyne	1
„ 11, 2·15 „	Birkrigg	Scotland, East	2
„ 13, 12·0 noon	Polbeth (Oil-shale)	Do.	1
„ 15, 11·0 p.m.	Glynca	South Wales	1
„ 23, 9·0 „	Ashmore Park	Staffordshire, South	1
„ 25, 10·45 a.m.	Slapewath	Durham	1
„ 27, 8·0 „	Cwmavon Slant	South Wales	1
June 3, 11·30 „	Pumpherston (Oil-shale)	Scotland, East	1
„ 4, 12·40 p.m.	Railey Fell	Durham	1
„ 5, 10·30 „	Tanfield Lea	Newcastle-upon-Tyne	2
„ 6, 7·0 a.m.	Hazlehead	Yorkshire	1
„ 9, 2·0 „	Bryn Navigation	South Wales	1
„ 13, 6·0 „	Tanhouse	Yorkshire	1
„ 17, 7·15 „	North Blaina	South Western	1
„ 22, 9·0 p.m.	South Rhondda	South Wales	1
„ 24, 10·0 a.m.	Redhill	Yorkshire	1
„ 28, 8·0 „	Pollok	Scotland, West	1
„ 30, 6·45 „	Thankerton	Do.	1
July 1, 1·45 p.m.	Kirkwood	Do.	1
„ 7, 8·30 a.m.	Tewgoed	South Wales	2
„ 7, 8·50 „	West Cannock	Staffordshire, South	5
„ 8, 3·45 p.m.	Throckley	Newcastle-upon-Tyne	1
„ 12, 6·0 a.m.	Valley	Yorkshire	1
„ 14, 3·0 p.m.	Meiklehill	Scotland, West	1
„ 20, 5·0 „	Cannock Chase	Staffordshire, South	1
„ 23, 6·15 a.m.	Cornsilloch	Scotland, East	1
„ 27, 12·0 noon	Pennyvenie	Scotland, West	1
„ 27, 6·30 p.m.	Blaen-cae-gurwen	South Wales	1
„ 29, 4·0 „	Woodhall	Scotland, West	2
Aug. 9, 11·0 a.m.	Brayton Domain (No. 4)	Newcastle-upon-Tyne	1
„ 10, 5·0 „	Tanhouse	Yorkshire	1
„ 11, 5·30 p.m.	Dyllas	South Wales	1
„ 12, 1·40 „	Souterhouse	Scotland, West	1
„ 14, 9·50 „	Caprington	Do.	1
„ 16, 9·0 „	Darranfawr	South Wales	3
„ 17, 11·0 a.m.	Glenclelland	Scotland, West	1
„ 17, 10·30 p.m.	Keumuirhill	Do.	1

TABLE III.—*Continued.*

1898.	Colliery.	Mines-Inspection Districts.	No. of Persons Injured.
Aug. 19, 9·30 a.m....	Cymmer Glyncorrwg...	South Wales	1
„ 19, 2·50 p.m....	Hodgen's Abercrave ...	Do.	2
„ 22, 1·30 „ ..	Llay Hall	Liverpool	2
„ 25, 8·30 a.m....	Cwmavon Slant ...	South Wales	1
„ 26, 3·30 „ ...	Velinfran	Do.	1
„ 27, 11·30 „ ...	Tong (No. 1)	Yorkshire	1
Sept. 6, 1·30 p.m....	Llynfi Valley	South Wales	1
„ 7, 8·0 a.m....	Bridgeness	Scotland, East ...	1
„ 9, 9·15 p.m....	Dalziel and Broomside	Scotland, West ...	2
„ 10, 7·0 a.m....	Glencraig	Scotland, East ...	1
„ 13, 2·0 „ ...	Cwmavon Slant ..	South Wales	1
„ 13, 2·0 p.m....	Bridgeness	Scotland, East ...	1
„ 17, 9·0 a.m....	Dalziel and Broomside	Scotland, West ...	1
„ 19, 8·20 „ ...	Llest	South Wales	1
„ 19, 9·0 p.m....	North Skelton ...	Durham	1
„ 20, 7·20 a.m....	Rosebank	Scotland, East ...	1
„ 27, 3·30 p.m....	Brownyside	Do. ...	1
„ 30, 1·0 a.m....	Backworth	Newcastle-upon-Tyne	1*
Oct. 5, 6·0 p.m....	Whitehill	Scotland, West ...	1
„ 7, 3·0 „ ...	Primrose	South Wales	1
„ 7, 4·0 „ ...	Blaen-cae-gurwen ...	Do.	1
„ 10, 6·45 a.m....	Newhouse	Scotland, West ...	2
„ 13, 8·0 „ ...	Glynea	South Wales	2
„ 24, 7·30 a.m....	Rheola	Do.	1
„ 24, 12·0 m'night	Crawshay's Cwm ...	Do.	1
„ 28, 1·30 p.m....	Westburn	Scotland, West ...	1
„ 29, 6·30 a.m....	Woodilee	Do. ...	1
„ 31, 4·30 „ ...	Motherwell	Scotland, East ...	2
„ 31, 7·0 „ ...	South Medomsley ...	Newcastle-upon-Tyne	2
„ 31, 7·30 „ ...	Longrigg	Scotland, East ...	1
Nov. 1, 11·0 „ ...	Darngavil	Do. ...	1
„ 2, 1·0 „ ...	Horseley	Staffordshire, South ...	2
„ 11, 7·10 „ ...	Gateside	Scotland, West ...	1
„ 17, 11·0 „ ...	Blairhall	Scotland, East ...	1
„ 17, 4·30 p.m....	Cwmavon Slant ...	South Wales	2
„ 20, 11·30 a.m....	Holmes (Oil-shale) ...	Scotland, East ...	1
„ 23, 12·45 „ ...	Rosehall	Scotland, West ...	1
„ 23, 8·40 „ ...	Foxley	Do. ...	2
„ 23, 9·0 „ ...	Cwrt-y-bettws ...	South Wales	1
„ 23, 1·30 p.m....	Alexandra	Liverpool	1
„ 24, 10·0 a.m....	Whitworth	South Western ...	1
„ 25, 12·50 p.m....	South Moor, Hedley Pit	Durham	1
„ 26, 7·45 a.m....	Cymmer Glyncorrwg...	South Wales	1
„ 28, 10·45 a.m....	Cymmer Glyncorrwg...	South Wales	2
„ 28, 6·0 p.m....	Arniston	Scotland, East ...	2
„ 30, 12·0 noon...	Broad Oak	Manchester	1
Dec. 5, 6·30 a.m....	Bourtreehill	Scotland, West ...	1
„ 5, 11·0 p.m....	Dalziel and Broomside	Do. ...	1
„ 7, 7·30 a.m....	West Longrigg ...	Scotland, East ...	1
„ 7, 4·0 p.m....	Moor Road, Chorley ...	Manchester	1
„ 14, 12·30 „ ...	Cartwright	Midland	1
„ 15, 5·40 a.m....	Glenboig (Fire-clay)...	Scotland, East ...	2
„ 15, 11·0 „ ...	Cwrt-y-bettws ...	South Wales	2
„ 16, 6·15 „ ...	Fairlie	Scotland, West ...	3
„ 26, 12·30 „ ..	Westrigg	Scotland, East ...	1
„ 27, 7·30 „ ...	Drumpeller	Scotland, West ...	1
„ 28, 10·0 „ ...	Addiewell (Oil-shale)..	Scotland, East ...	1
„ 29, 10·30 „ ...	Monkland	Do. ...	1
		Total	201

TABLE IV.—BAROMETER, THERMOMETER, ETC., READINGS, 1898.

JANUARY, 1898.

KEW.								GLASGOW.							
	BAROMETER.				TEMPERATURE.		Direction of wind at noon		BAROMETER.				TEMPERATURE.		Direction of wind at noon
Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max	Min.		Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max	Min.	
1	29·308	29·327	29·314	29·345	44·3	40·8	E	1	29·117	29·250	29·356	29·456	42·3	38·3	SSW
2	29·438	29·664	29·838	30·002	46·1	32·9	W	2	29·531	29·674	29·795	29·953	42·6	39·3	WSW
3	30·122	30·228	30·220	30·241	45·1	30·2	W	3	30·070	30·163	30·136	30·063	40·1	33·4	ENE
4	30·210	30·241	30·186	30·117	47·4	30·0	WSW	4	29·905	29·872	29·814	29·799	46·1	38·9	WSW
5	30·013	29·962	29·884	29·881	51·6	46·5	SW	5	29·725	29·793	29·700	29·586	43·6	31·2	NE
6	29·873	29·932	29·922	29·904	53·7	45·3	W	6	29·521	29·622	29·688	29·726	48·6	39·8	W
7	29·822	30·010	30·106	30·163	47.8	30·9	NW	7	29·704	29·811	29·892	29·860	42·1	34·9	W
8	30·105	30·034	29·917	29·866	46·0	27·6	SE	8	29·710	29·642	29·653	29·694	47·1	38·6	SW
9	29·829	29·883	29·952	30·045	42·0	38·0	N	9	29·743	29·845	29·918	29·972	44·9	38·5	W
10	30·120	30·223	30·248	30·330	43·2	28·9	N	10	30·001	29·997	29·963	30·013	46·4	38·6	SW
11	30·367	30·445	30·458	30·502	46·0	28·2	SW	11	30·079	30·123	30·081	30·103	49·9	43·2	SSW
12	30·509	30·580	30·574	30·268	48·7	41·1	SW	12	30·118	30·294	30·399	30·462	50·1	42·0	WSW
13	30·607	30·621	30·545	30·511	47·1	42·2	SE	13	30·399	30·385	30·340	30·307	48·5	40·1	SW
14	30·447	30·467	30·405	30·510	43·1	41·1	SE	14	30·281	30·304	30·320	30·381	47·8	43·3	SW
15	30·521	30·594	30·578	30·613	43·3	35·1	SE	15	30·390	30·430	30·423	30·441	45·1	42·2	SW
16	30·596	30·604	30·530	30·517	38·8	34·9	SE	16	30·404	30·382	30·287	30·233	46·0	40·3	SW
17	30·461	30·466	30·436	30·423	36·6	31·8	SE	17	30·162	30·133	30·096	30·056	48·9	45·3	SW
18	30·377	30·380	30·324	30·353	50·6	36·6	SSW	18	29·935	29·799	29·761	29·853	49·5	45·8	SW
19	30·329	30·328	30·283	30·296	52·1	47·9	SW	19	29·787	29·778	29·707	29·959	53·4	43·5	WSW
20	30·298	30·355	30·350	30·398	52·4	48·3	SW	20	30·057	30·104	30·131	30·170	45·4	38·1	NE
21	30·409	30·456	30·446	30·480	53·8	50·0	SW	21	30·105	30·185	30·284	30·195	46·5	41·3	NW
22	30·436	30·434	30·433	30·548	53·9	41·9	W	22	30·018	30·159	30·375	30·466	49·4	37·0	W
23	30·599	30·635	30·558	30·563	44·2	33·9	NE	23	30·467	30·439	30·377	30·379	49·4	35·3	SW
24	30·541	30·531	30·498	30·504	46·2	43·8	W	24	30·354	30·367	30·352	30·325	48·3	45·2	WSW
25	30·488	30·494	30·440	30·417	44·8	42·6	SW	25	30·266	30·236	30·152	30·132	47·6	45·2	SW
26	30·388	30·398	30·379	30·387	45·5	42·5	SW	26	30·068	30·077	30·066	30·062	47·9	46·2	SW
27	30·383	30·382	30·438	30·501	46·1	42·2	W	27	30·081	30·182	30·229	30·306	49.7	46·8	W
28	30·552	30·624	30·613	30·663	43·6	40·7	SW	28	30·358	30·404	30·368	30·370	49·2	44·8	SW
29	30·653	30·658	30·571	30·509	46·6	37·9	SSW	29	30·315	30·221	30·025	29·950	51·5	45·9	WSW
30	30·432	30·365	30·239	30·126	54·6	46·6	SW	30	29·965	29·874	29·743	29·578	52·1	49·2	WSW
31	30·060	30·385	30·474	30·369	55·0	44·8	NW	31	29·969	30·207	30·166	29·916	51·9	42·3	SW

FEBRUARY, 1898.

1	30·210	30·231	30·130	29·993	56·3	46·6	W	1	29·906	29·868	29·606	29·464	52·9	44·9	SW
2	29·871	29·794	29·719	29·848	52·0	40·0	W	2	29·208	29·171	29·394	29·762	45·7	37·9	WNW
3	29·987	30·025	29·770	29·589	47·1	37·2	W	3	29·801	29·659	29·510	29·478	42·0	34·8	W
4	29·458	29·322	29·361	29·553	44·7	32·9	N	4	29·396	29·415	29·515	29·685	37·8	32·5	N
5	29·716	29·869	29·949	29·995	40·0	32·0	NW	5	29·815	29·901	29·849	29·650	37·3	31·4	NW
6	29·875	29·706	29·735	29·782	47·0	33·8	WNW	6	29·443	29·461	29·459	29·457	42·9	33·0	WNW
7	29·775	29·788	29·868	30·010	44·6	34·1	WNW	7	29·451	29·605	29·735	29·766	39·5	31·3	NW
8	30·032	30·038	30·015	30·099	47·0	33·7	W	8	29·740	29·818	29·895	29·980	44·4	37·1	NW
9	30·158	30·228	30·243	30·261	46·7	31·4	WNW	9	29·900	29·940	29·904	29·880	45·6	37·9	WSW
10	30·258	30·286	30·279	30·288	49·2	40·6	SW	10	29·886	29·935	29·912	29·852	51·3	44·7	WSW
11	30·270	30·297	30·292	30·338	48·8	44·0	SSW	11	29·810	29·971	30·041	30·073	48·0	42·9	W
12	30·323	30·326	30·221	30·165	51·6	44·0	SW	12	30·005	29·859	29·628	29·780	46·4	37·8	SW
13	30·094	30·084	30·113	30·134	47·1	41·0	N	13	29·859	29·852	29·790	29·691	42·2	35·2	SW
14	30·104	30·195	30·278	30·345	51·4	39·6	W	14	29·711	29·891	29·980	29·966	47·3	40·3	WSW
15	30·291	30·222	30·138	30·084	53·4	42·5	SW	15	29·762	29·626	29·707	29·614	51·3	43·5	W
16	30·073	30·123	30·094	30·129	51·9	42·7	WNW	16	29·634	29·748	29·865	30·020	44·7	36·9	WNW
17	30·157	30·154	30·017	29·890	46·1	40·8	W	17	30·032	29·996	29·903	29·844	41·7	36·4	W
18	29·789	29·814	29·857	29·931	43·0	33·3	NNE	18	29·860	29·917	29·948	29·978	39·2	31·6	NE
19	29·943	29·927	29·791	29·654	40·0	30·4	W	19	29·896	29·704	29·451	29·240	43·1	29·4	WSW
20	29·435	29·278	29·242	29·250	45·5	32·0	WNW	20	29·135	29·165	29·075	28·969	41·6	29·3	NW
21	29·192	29·174	29·182	29·252	40·9	26·0	SE	21	29·072	29·199	29·243	29·317	39·7	28·3	WNW
22	29·266	29·355	29·424	29·533	41·2	33·8	NE	22	29·380	29·506	29·611	29·739	40·8	34·3	NNE
23	29·611	29·766	29·823	29·965	43·4	33·2	N	23	29·821	29·926	29·977	30·060	41·3	30·5	N
24	30·019	30·108	30·117	30·161	42·1	31·2	N	24	30·073	30·093	30·052	30·016	41·2	27·8	SW
25	30·182	30·109	30·039	29·919	46·8	27·4	WSW	25	29·911	29·807	29·590	29·437	43·8	35·9	SE
26	29·917	30·038	30·056	30·089	46·7	34·6	W	26	29·548	29·632	29·685	29·685	42·6	34·6	W
27	30·022	30·006	29·845	29·911	46·4	35·9	SW	27	29·616	29·640	29·641	29·660	43·1	36·1	W
28	29·926	29·981	29·973	29·946	46·9	33·6	W	28	29·686	29·727	29·673	29·559	42·1	34·8	W

MARCH, 1898.

KEW.								GLASGOW.							
	Barometer.				Temperature.				Barometer.				Temperature.		
Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max	Min.	Direction of wind at noon	Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max	Min.	Direction of wind at noon
1	29·821	29·679	29·597	29·630	51·0	36·2	W	1	29·385	29·323	29·308	29·348	39·1	32·9	WNW
2	29·611	29·675	29·710	29·761	47·1	35·0	NW	2	29·456	29·601	29·652	29·698	43·8	34·1	NW
3	29·756	29·767	29·725	29·762	43·1	30·9	NW	3	29·732	29·769	29·784	29·878	41·6	30·3	NW
4	29·761	29·824	29·809	29·835	43·2	33·7	N	4	29·925	29·942	29·951	29·978	41·7	33·8	N
5	29·810	29·831	29·786	29·771	41·1	30·0	N	5	29·898	29·795	29·644	29·600	39·9	29·2	SSW
6	29·727	29·718	29·712	29·823	44·2	27·1	S	6	29·581	29·635	29·707	29·869	41·4	34·1	ESE
7	29·894	29·995	30·003	30·054	42·0	31·9	NE	7	29·979	30·101	30·137	29·197	39·9	30·7	ENE
8	30·008	29·993	29·974	30·009	40·1	34·1	NNE	8	30·185	30·169	30·109	30·095	42·3	30·4	N
9	30·031	30·116	30·123	30·181	43·6	37·3	NNE	9	30·056	30·103	30·117	30·158	45·3	35·4	W
10	30·118	30·220	30·187	30·228	45·7	31·6	NNE	10	30·123	30·139	30·143	30·189	48·3	40·1	W
11	30·212	30·204	30·117	30·086	45·1	32·4	NE	11	30·158	30·135	30·044	29·993	50·5	43·5	W
12	30·022	30·023	30·004	30·040	41·1	30·6	N	12	29·905	29·885	29·897	29·983	47·1	37·5	W
13	30·045	30·072	30·008	29·999	48·1	28·7	N	13	29·961	29·885	29·703	29·662	47·2	36·1	WSW
14	29·939	29·927	29·944	30·037	50·1	35·0	W	14	29·650	29·803	29·878	29·896	44·4	36·9	NW
15	30·035	30·027	29·917	29·900	50·9	30·9	SW	15	29·751	29·575	29·544	29·629	48·8	37·4	WSW
16	29·895	29·965	29·986	30·042	54 2	44·8	WNW	16	29·706	29·768	29·759	29·768	47·9	42 0	WSW
17	30·033	30·018	29·965	29·970	53·8	43·8	W	17	29·667	29·602	29·594	29·603	52·1	46·2	W
18	29·967	29·964	29·924	29·920	57·4	49·1	W	18	29·556	29·470	29·449	29·449	55·1	48·8	SW
19	29·859	29·864	29·861	29·980	55·4	40·1	WSW	19	29·605	29·778	29·870	29·984	49·6	35·8	WNW
20	30·018	30·127	30·136	30·204	48·0	34·0	NE	20	30·076	30·124	30·106	30·114	45·7	30·9	W
21	30·200	30·222	30·157	30·173	49·7	28·0	N	21	30·117	30·140	30·122	30·128	48·4	36·0	W
22	30·163	30·162	30·071	30·040	50·0	29·2	N	22	30·071	30·040	29·977	29·865	47·5	39·4	WSW
23	29·951	29·771	29·697	29·812	49·1	32·1	W	23	29·705	29·893	30·003	30·076	49·2	39·3	NE
24	29·799	29·727	29·770	29·834	40·0	29·2	N	24	30·055	30·128	30·229	30·351	43·4	36·5	NE
25	29·831	29·824	29·853	29·818	36·1	33·1	N	25	30·355	30·358	30·336	30·317	42·5	35·2	ENE
26	29·674	29·510	29·340	29·317	39·2	35·0	N	26	30·203	30·106	29·943	29·862	39·9	31·5	NE
27	29·330	29·411	29·406	29·434	42·2	35·9	NW	27	29·840	29·832	29·779	29·719	42·1	35·3	ENE
28	29·396	29·412	29·410	29·443	41·1	35·0	N	28	29·617	29·543	29·518	29·478	42·1	33·8	ENE
29	29·436	29·456	29·443	29·472	46·0	33·2	WSW	29	29·365	29·332	29·345	29·437	38·0	33·1	S
30	29·474	29·518	29·516	29·609	52·7	26·3	SW	30	29·470	29·545	29·559	29·610	45·5	33·4	NE
31	29·641	29·706	29·737	29·827	50·1	38·6	ESE	31	29·677	29·736	29·755	29·800	47·4	32·4	W

APRIL, 1898.

1	29·860	29·901	29·825	29·831	50·6	31·9	NE	1	29·797	29·813	29·789	29·790	51·9	37·9	WNW
2	29·798	29·791	29·736	29·767	51·9	35·8	NW	2	29·679	29·591	29·506	29·560	49·3	40·2	WSW
3	29·769	29·824	29·818	29·847	54·8	43·3	W	3	29·552	29·554	29·472	29·475	48·2	38·4	SW
4	29·790	29·823	29·905	30·049	52·8	36·2	NW	4	29·562	29·729	29·870	30·014	47·4	34·5	NW
5	30·120	30·184	30·139	30·180	51·6	30·7	NW	5	30·047	30·054	30·081	29·920	47·4	29·8	SW
6	30·137	30·128	30·085	30·127	58·1	28·7	SW	6	29·823	29·773	29·750	29·797	52·3	42·0	SW
7	30·136	30·194	30·208	30·239	59·4	46·5	SW	7	29·832	29·875	29·906	29·953	54·5	48·1	E
8	30·235	30·227	30·103	30·050	64·0	35·8	SSW	8	29·948	29·948	29·860	29·724	57·0	45·6	SSW
9	29·899	29·832	29·900	29·955	59·1	47·8	W	9	29·506	29·481	29·561	29·522	56·1	48·9	W
10	29·813	29·722	29·663	29·695	57·9	48·3	SW	10	29·298	29·283	*	29·247	55·8	45·0	WSW
11	29·754	29·756	29·595	29·346	57·9	45·6	SW	11	*	29·382	*	29·412	52·8	44·1	WSW
12	29·390	29·648	29·783	29·940	54·5	41·1	NW	12	*	29·596	29·669	29·715	51·4	39·9	WNW
13	29·999	30·033	29·982	29·970	57·0	37·1	S	13	29·671	29·601	29·566	29·598	51·1	43·8	S
14	29·883	29·841	29·737	29·698	58·1	44·2	S	14	29·664	29·700	29·677	29·700	53·9	40·6	S
15	29·662	29·768	29·793	29·912	57·2	42·3	W	15	29·672	29·670	29·672	29·756	51·1	41·0	NNW
16	29·947	30·003	29·945	30·017	59·1	37·1	SW	16	29·806	29·867	29 863	29·870	53·1	39·4	WSW
17	29·909	29·974	29·871	29·843	59·7	35·7	SW	17	29·800	29·792	29·721	29·681	50·9	44·3	SSW
18	29·774	29·763	29·714	29·790	55·0	39·3	E	18	29·621	29·645	29·654	29·733	56·7	44·6	SSW
19	29·826	29·900	29·897	29·972	54·8	41·6	E	19	29·781	29·830	29·825	29·848	53·3	44·1	SSW
20	29·997	30·017	30·022	30·104	59·9	40·2	S	20	29·849	29·879	29·947	29·932	49·5	42·0	SSW
21	30·128	30·181	30·157	30·171	55·8	40·0	E	21	30·064	30·124	30·113	30·109	58·4	47·1	NW
22	30·132	30·105	30·021	30·035	47·9	35·8	NE	22	30·083	30·041	29·961	29·955	59·0	44·3	NW
23	30·040	30·071	30·043	30·130	51·9	34·0	WNW	23	29·943	29·947	29·923	29·935	54·4	42·8	E
24	30·135	30·166	30·137	30·174	53·3	29·9	ENE	24	30·026	30·101	30·122	30·157	54·1	43·9	WNW
25	30·143	30·123	30·051	30·011	52·3	34·7	E	25	30·139	30·121	30·026	30·001	54·8	42·3	WNW
26	29·908	29·840	29·661	29·592	58·2	43·0	NE	26	29·956	29·922	29·856	29·830	48·3	40·3	E
27	29·527	29·535	29·531	29·570	58·0	43·4	SSE	27	29·750	29·700	29·648	29·607	50·4	43·5	E
28	29·563	29·572	29·562	29·575	58·1	42·7	NW	28	29·581	29·598	29·594	29·597	52·2	44·1	ENE
29	29·552	29·555	29·535	29·611	59·0	44·5	S	29	29·487	29·475	29·468	29·460	48·6	42·9	E
30	29·625	29·529	29·559	29·764	56·0	41·2	SSE	30	29·437	29·424	29·324	29·280	54·8	42·5	ESE

* No record.

MAY, 1898.

KEW.								GLASGOW.							
	Barometer.				Temperature.		Direction of wind at noon		Barometer.				Temperature.		Direction of wind at noon
Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max	Min.		Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max	Min.	
1	29·849	29·840	29·726	29·699	53·0	40·1	SE	1	29·438	29·622	29·647	29·692	56·8	44·1	WSW
2	29·631	29·497	29·445	29·519	67·3	48·2	SE	2	29·656	29·633	29·514	29·347	52·0	42·4	E
3	29·535	29·529	29·485	29·490	61·0	47·3	S	3	29·255	29·274	29·255	29·283	56·8	42·9	SSE
4	29·389	29·491	29·675	29·823	56·6	46·1	W	4	29·277	29·312	29·382	29·510	52·7	45·9	WSW
5	29·841	29·842	29·718	29·647	56·1	45·3	S	5	29·564	29·625	29·662	29·726	55·3	43·2	WSW
6	29·710	29·923	30·075	30·253	59·7	45·1	NW	6	29·821	30·004	30·105	30·209	61·1	42·3	N
7	30·290	30·330	30·291	30·268	62·0	41·7	N	7	30·223	30·210	30·135	30·069	58·8	41·1	WSW
8	30·206	30·153	30·074	30·037	55·8	48·2	SW	8	29·974	29·959	29·914	29·908	56·1	48·4	WSW
9	30·021	30·044	29·997	29·984	62·8	49·6	NW	9	29·899	29·914	29·883	29·881	58·6	47·1	WNW
10	29·912	29·859	29·747	29·574	61·9	50·0	W	10	29·809	29·710	29·448	29·225	50·8	43·2	ENE
11	29·298	29·253	29·218	29·200	57·0	47·6	W	11	28·909	28·846	28·988	29·134	48·1	39·6	WNW
12	29·165	29·246	29·378	29·534	53·2	39·6	N	12	29·217	29·293	29·333	29·421	49·5	35·3	NW
13	29·616	29·685	29·689	29·673	55·4	36·3	SW	13	29·452	29·487	29·503	29·550	52·6	36·5	NW
14	29·606	29·652	29·735	29·818	59·2	44·8	W	14	29·591	29·651	29·702	29·765	54·4	33·3	WNW
15	29·800	29·820	29·863	29·921	54·7	42·0	NE	15	29·762	29·798	29·837	29·940	51·4	40·3	WSW
16	30·003	30·110	30·141	30·205	55·0	43·0	N	16	30·023	30·057	30·062	30·091	51·8	35·1	W
17	30·205	30·174	30·086	30·105	57·2	37·4	W	17	30·045	29·987	30·043	30·182	46·7	37·4	ESE
18	30·149	30·190	30·151	30·142	55·3	41·1	NW	18	30·262	30·292	30·263	30·280	59·0	35·4	NE
19	29·994	29·876	29·752	29·761	50·5	40·5	NNE	19	30·248	30·226	30·150	30·144	54·6	40·3	E
20	29·711	29·700	29·608	29·641	51·6	49·8	N	20	30·101	30·071	30·031	30·059	61·9	42·3	E
21	29·643	29·731	29·775	29·803	59·9	49·1	S	21	29·985	29·954	29·881	29·842	62·2	49·8	E
22	29·791	29·764	29·701	29·729	70·9	47·8	ESE	22	29·794	29·815	29·798	29·850	56·9	47·3	ENE
23	29·696	29·697	29·682	29·729	71·7	48·3	E	23	29·844	29·842	29·826	29·865	55·9	45·6	E
24	29·728	29·778	29·770	29·814	65·2	51·0	E	24	29·845	29·852	29·813	29·834	62·2	46·3	NE
25	29·784	29·772	29·720	29·760	58·0	47·3	N	25	29·807	29·768	29·726	29·762	61·9	44·3	NE
26	29·745	29·790	29·789	29·853	58·1	46·3	NNW	26	29·770	29·776	29·767	29·832	59·6	40·9	NW
27	29·894	29·949	29·940	29·962	61·2	46·2	ESE	27	29·862	29·876	29·891	29·930	53·9	41·8	W
28	29·985	30·035	30·043	30·093	59·8	48·4	NNW	28	29·964	30·017	30·026	30·018	56·1	42·1	WNW
29	30·097	30·086	30·010	29·946	61·2	46·8	NW	29	29·918	29·919	29·766	29·781	54·8	45·9	W
30	29·859	29·895	29·841	29·796	57·3	49·5	WNW	30	29·800	29·756	29·695	29·668	53·0	39·4	W
31	29·703	29·581	29·462	29·558	59·5	41·7	WSW	31	29·577	29·529	29·443	29·476	52·2	40·1	WNW

JUNE, 1898.

1	29·523	29·578	29·602	29·656	56·9	41·4	NW	1	29·421	29·367	29·393	29·478	52·5	43·4	WNW
2	29·648	29·673	29·731	29·897	59·1	45·7	WSW	2	29·525	29·634	29·689	29·776	59·9	42·4	WNW
3	29·961	29·987	29·944	29·955	61·7	42·8	SW	3	29·735	29·671	29·597	29·593	53·5	45·2	SW
4	29·916	29·922	29·887	29·901	62·9	49·0	SSW	4	29·580	29·629	29·651	29·695	59·0	47·4	SW
5	29·846	29·811	29·785	29·830	72·2	47·9	SE	5	29·721	29·767	29·747	29·737	58·0	50·9	SE
6	29·789	29·808	29·808	29·877	69·3	51·0	SE	6	29·670	29·620	29·608	29·699	63·5	52·2	SE
7	29·939	30·007	29·990	30·019	72·0	53·3	SW	7	29·796	29·881	29·909	29·967	65·4	49·4	WSW
8	30·034	30·046	30·059	30·092	63·6	49·1	W	8	29·995	30·024	30·067	30·143	67·2	47·0	SSW
9	30·089	30·092	30·063	30·055	67·1	56·4	N	9	30·195	30·195	30·182	30·217	67·9	47·3	W
10	30·019	30·048	30·060	30·093	62·0	53·3	N	10	30·230	30·218	30·192	30·233	66·9	48·0	E
11	30·098	30·112	30·112	30·204	70·8	50·7	NE	11	30·236	30·245	30·198	30·234	62·4	48·1	E
12	30·212	30·239	30·214	30·207	55·6	50·0	NE	12	30·227	30·225	30·210	30·262	62·0	45·9	E
13	30·214	30·240	30·220	30·245	56·2	48·0	NE	13	30·275	30·297	30·274	30·310	62·6	48·9	E
14	30·246	30·246	30·228	30·242	55·0	48·9	NNE	14	30·311	30·305	30·237	30·252	66·0	48·1	WNW
15	30·234	30·245	30·188	30·209	59·5	46·2	NE	15	30·236	30·227	30·185	30·214	70·1	46·9	WSW
16	30·215	30·220	30·205	30·227	62·2	44·9	NNE	16	30·207	30·194	30·127	30·143	69·6	51·8	E
17	30·234	30·249	30·197	30·209	70·5	48·0	SW	17	30·136	30·116	30·069	30·034	69·3	47·1	SW
18	30·184	30·148	30·093	30·101	73·6	52·3	WSW	18	29·916	29·828	29·867	29·956	64·9	54·7	W
19	30·082	30·091	30·070	30·085	71·8	58·5	NW	19	29·966	29·993	29·989	29·929	62·8	52·3	W
20	30·055	30·034	29·990	30·000	73·1	54·2	W	20	29·793	29·786	29·800	29·776	59·1	51·6	WSW
21	29·943	29·915	29·827	29·802	74·6	57·5	SW	21	29·759	29·735	29·612	29·610	63·9	50·5	W
22	29·769	29·773	29·755	29·833	68·2	51·8	NW	22	29·544	29·609	29·622	29·660	58·7	49·1	W
23	29·864	29·921	29·921	29·896	65·8	47·5	W	23	29·708	29·735	29·646	29·410	57·3	47·3	SW
24	29·758	29·689	29·611	29·561	61·7	54·1	SW	24	29·361	29·360	29·278	29·271	60·2	51·3	SW
25	29·515	29·469	29·444	29·481	62·9	49·9	SW	25	29·277	29·298	29·319	29·420	62·1	47·0	WSW
26	29·473	29·530	29·581	29·678	60·6	47·3	N	26	29·516	29·647	29·735	29·854	63·0	48·9	NE
27	29·721	29·758	29·812	29·914	62·3	50·0	N	27	29·875	29·919	29·897	29·905	61·3	51·1	E
28	29·943	29·996	29·978	29·998	66·6	50·7	N	28	29·917	29·914	29·881	29·890	68·8	44·6	SW
29	30·007	30·018	29·992	30·007	71·7	51·2	WSW	29	29·877	29·876	29·873	29·891	61·6	55·9	SW
30	30·044	30·063	30·055	30·096	72·1	57·5	SW	30	29·913	29·979	30·024	30·055	61·9	53·7	W

MARCH, 1898.

	KEW.								GLASGOW.						
	Barometer.				Temperature.				Barometer.				Temperature.		
Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max	Min.	Direction of wind at noon	Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max	Min.	Direction of wind at noon
1	29·821	29·679	29·597	29·630	51·0	36·2	W	1	29·385	29·323	29·308	29·348	39·1	32·9	WNW
2	29·611	29·675	29·710	29·761	47·1	35·0	NW	2	29·456	29·601	29·652	29·698	43·8	34·1	NW
3	29·756	29·767	29·725	29·762	43·1	30·9	NW	3	29·732	29·769	29·784	29·878	41·6	30·3	NW
4	29·761	29·824	29·809	29·835	43·2	33·7	N	4	29·925	29·942	29·951	29·978	41·7	33·8	N
5	29·810	29·831	29·786	29·771	41·1	30·0	N	5	29·898	29·795	29·644	29·600	39·9	29·2	SSW
6	29·727	29·718	29·712	29·823	44·2	27·1	S	6	29·581	29·635	29·707	29·869	41·4	34·1	ESE
7	29·894	29·995	30·003	30·054	42·0	31·9	NE	7	29·979	30·101	30·137	29·197	39·9	30·7	ENE
8	30·008	29·993	29·974	30·009	40·1	34·1	NNE	8	30·185	30·169	30·109	30·095	42·3	30·4	N
9	30·031	30·116	30·123	30·181	43·6	37·3	NNE	9	30·056	30·103	30·117	30·158	45·3	35·4	W
10	30·118	30·220	30·187	30·228	45·7	31·6	NNE	10	30·123	30·139	30·143	30·189	48·3	40·1	W
11	30·212	30·204	30·117	30·086	45·1	32·4	NE	11	30·158	30·135	30·044	29·993	50·5	43·5	W
12	30·022	30·023	30·004	30·040	41·1	30·6	N	12	29·905	29·885	29·897	29·983	47·1	37·5	W
13	30·045	30·072	30·008	29·999	48·1	28·7	N	13	29·961	29·885	29·703	29·662	47·2	36·1	WSW
14	29·939	29·927	29·944	30·037	50·1	35·0	W	14	29·650	29·803	29·878	29·896	44·4	36·9	NW
15	30·035	30·027	29·917	29·900	50·9	30·9	SW	15	29·751	29·575	29·544	29·629	48·8	37·4	WSW
16	29·895	29·965	29·986	30·042	54 2	44·8	WNW	16	29·706	29·768	29·759	29·768	47·9	42 0	WSW
17	30·033	30·018	29·965	29·970	53·8	43·8	W	17	29·667	29·602	29·594	29·603	53·1	46·2	W
18	29·967	29·964	29·924	29·920	57·4	49·1	W	18	29·556	29·470	29·449	29·449	55·1	48·8	SW
19	29·859	29·864	29·861	29·980	55·4	40·1	WSW	19	29·605	29·778	29·870	29·984	49·6	35·8	WNW
20	30·018	30·127	30·136	30·204	48·0	34·0	NE	20	30·076	30·124	30·106	30·114	45·7	30·9	W
21	30·200	30·222	30·157	30·173	49·7	28·0	N	21	30·117	30·140	30·122	30·128	48·4	36·0	W
22	30·163	30·162	30·071	30·040	50·0	29·2	N	22	30·071	30·040	29·977	29·865	47·5	39·4	WSW
23	29·951	29·771	29·697	29·812	49·1	32·1	W	23	29·705	29·893	30·003	30·076	49·2	39·3	NE
24	29·799	29·727	29·770	29·834	40·0	29·2	N	24	30·055	30·128	30·229	30·351	43·4	36·5	NE
25	29·831	29·824	29·853	29·818	36·1	33·1	N	25	30·355	30·358	30·336	30·317	42·5	35·2	ENE
26	29·674	29·510	29·340	29·317	39·2	35·0	N	26	30·203	30·106	29·943	29·862	39·9	31·5	NE
27	29·330	29·411	29·406	29·434	42·2	35·9	NW	27	29·840	29·832	29·779	29·719	42·1	35·3	ENE
28	29·396	29·412	29·410	29·443	41·1	35·0	N	28	29·617	29·543	29·518	29·478	42·1	33·8	ENE
29	29·436	29·456	29·443	29·472	46·0	33·2	WSW	29	29·365	29·332	29·345	29·437	38·0	33·1	S
30	29·474	29·518	29·516	29·609	52·7	26·3	SW	30	29·470	29·545	29·559	29·640	45·5	33·4	NE
31	29·641	29·706	29·737	29·827	50·1	38·6	ESE	31	29·677	29·736	29·755	29·800	47·4	32·4	W

APRIL, 1898.

1	29·860	29·901	29·825	29·831	50·6	31·9	NE	1	29·797	29·813	29·789	29·790	51·9	37·9	WNW
2	29·798	29·791	29·736	29·767	51·9	35·8	NW	2	29·679	29·591	29·506	29·560	49·3	40·2	WSW
3	29·769	29·824	29·818	29·847	54·8	43·3	W	3	29·552	29·554	29·472	29·475	48·2	38·4	SW
4	29·790	29·823	29·905	30·049	52·8	36·2	NW	4	29·562	29·729	29·870	30·014	47·4	34·5	NW
5	30·120	30·184	30·139	30·180	51·6	30·7	NW	5	30·047	30·054	30·081	29·920	47·4	29·8	SW
6	30·137	30·128	30·085	30·127	58·1	28·7	SW	6	29·823	29·773	29·750	29·797	52·3	42·0	SW
7	30·136	30·194	30·208	30·238	59·4	46·5	SW	7	29·832	29·875	29·906	29·953	54·5	48·1	E
8	30·235	30·227	30·103	30·050	64·0	35·8	SSW	8	29·948	29·948	29·860	29·724	57·0	45·6	SSW
9	29·899	29·832	29·900	29·955	59·1	47·8	W	9	29·506	29·481	29·561	29·522	56·1	48·9	W
10	29·813	29·722	29·663	29·695	57·9	48·3	SW	10	29·298	29·283	*	29·247	55·8	45·0	WSW
11	29·754	29·756	29·595	29·346	57·9	45·6	SW	11	*	29·382	*	29·412	52·8	44·1	WSW
12	29·390	29·648	29·783	29·940	54·5	41·1	NW	12	*	29·596	29·669	29·715	51·4	39·9	WNW
13	29·999	30·033	29·982	29·970	57·0	37·1	S	13	29·671	29·601	29·566	29·598	51·1	43·8	S
14	29·883	29·841	29·737	29·698	58·1	44·2	S	14	29·664	29·700	29·677	29·700	53·9	40·6	S
15	29·662	29·768	29·793	29·912	57·2	42·3	W	15	29·672	29·670	29·672	29·756	51·1	41·0	NNW
16	29·947	30·003	29·945	30·017	59·1	37·1	SW	16	29·806	29·867	29 863	29·870	53·1	39·4	WSW
17	29·909	29·974	29·871	29·843	59·7	35·7	SW	17	29·800	29·792	29·721	29·681	50·9	44·3	SSW
18	29·774	29·763	29·714	29·790	55·0	39·3	E	18	29·621	29·645	29·654	29·733	56·7	44·6	SSW
19	29·826	29·900	29·897	29·972	54·8	41·6	E	19	29·781	29·830	29·825	29·848	53·3	44·1	SSW
20	29·997	30 017	30·022	30·104	59·9	40·2	S	20	29·849	29·879	29·947	29·932	49·5	42·0	SSW
21	30·128	30·181	30·157	30·171	55·8	40·0	E	21	30·064	30·124	30·113	30·109	58·4	47·1	NW
22	30·132	30·105	30·021	30·035	47·9	35·8	NE	22	30·083	30·041	29·961	29·955	59·0	44·3	NW
23	30·040	30·071	30·043	30·130	51·9	34·0	WNW	23	29·943	29·947	29·923	29·935	54·4	42·6	E
24	30·135	30·166	30·137	30·174	53·3	29·9	ENE	24	30·026	30·101	30·122	30·157	54·1	43·9	WNW
25	30·143	30·123	30·051	30·011	52·3	34·7	E	25	30·139	30·121	30·026	30·001	54·8	42·3	WNW
26	29·908	29·840	29·661	29·592	58·2	43·0	NE	26	29·956	29·922	29·856	29·830	48·3	40·3	E
27	29·527	29·535	29·531	29·570	58·0	43·4	SSE	27	29·750	29·700	29·648	29·607	50·4	42·5	E
28	29·563	29·572	29·562	29·575	58·1	42·7	NW	28	29·581	29·598	29·594	29·597	52·2	44·1	ENE
29	29·552	29·555	29·535	29·611	59·0	44·5	S	29	29·487	29·475	29·468	29·460	48·6	42·9	E
30	29·625	29·529	29·559	29·764	56·0	41·2	SSE	30	29·437	29·424	29·324	29·280	54·8	42·5	ESE

* No record.

GLASGOW.

TER.		TEMPERATURE.		Direction of wind at noon
4 P.M.	10 P.M.	Max	Min.	
30·140	30·119	58·1	49·1	W
30·027	30·101	63·8	53·3	W
30·254	30·299	67·6	60·2	W
30·267	30·247	75·8	55·6	WNW
30·137	30·120	76·8	56·1	SW
29·950	29·930	77·5	62·2	SE
29·880	29·883	71·9	60·2	SSE
29·869	29·852	64·7	60·5	SW
29·788	29·784	61·6	54·3	W
29·784	29·794	63·0	54·2	WSW
29·635	29·706	60·3	54·1	WSW
29·921	29·917	57·1	48·9	W
29·839	29·869	60·2	52·0	WSW
30·060	30·166	64·6	53·9	WNW
30·224	30·212	67·7	53·1	ENE
29·966	29·915	72·6	56·8	S
29·673	29·644	71·8	58·8	SSW
29·780	29·884	64·1	48·4	WNW
29·878	29·885	56·9	45·4	SSE
29·712	29·778	61·6	53·1	SW
29·942	30·001	57·7	47·1	W
30·132	30·210	53·4	38·0	WNW
30·198	30·203	54·8	39·2	S
30·082	30·092	53·3	37·3	E
30·012	30·031	51·5	43·2	E
29·856	29·795	56·8	43·1	NE
29·533	29·462	56·8	47·2	N
29·722	29·764	53·1	45·2	WNW
29·615	29·575	50·0	43·2	ESE
29·938	30·053	54·3	49·8	E

30·160	30·191	56·6	49·3	SW
30·230	30·253	62·4	56·2	WSW
30·272	30·306	59·8	53·9	WSW
30·318	30·338	65·3	49·2	NNE
30·225	30·236	58·7	45·1	E
30·091	30·112	57·7	52·3	E
29·988	29·981	54·0	51 7	ENE
29·909	29·952	60·3	49·7	E
29·908	29·958	56·1	45·3	ESE
30·010	30·029	53·1	46·1	NE
30·024	30·068	54·1	46·3	WNW
29·939	29·922	50·7	37·5	S
29·812	29·799	54·3	41·5	SE
29·604	29·563	55·3	46·9	ESE
29·362	29·344	49·1	44·9	E
29·286	29·248	49·9	41·7	E
29·128	29·110	46·4	41·6	E
29·222	29·354	45·9	42·2	E
29·473	29·534	54·9	43·1	NE
29·540	29·500	53·9	50·6	SE
29·563	29·575	56·1	51·1	SSW
29·442	29·576	60·0	52·4	WSW
29·865	29·860	55·4	47·4	WSW
29·565	29·541	50·6	42·1	WSW
29·564	29·581	55·1	43·2	W
29·706	29·704	55·3	48·6	WSW
29·792	29·786	58·1	46·8	WSW
29·682	29·629	50·5	45·2	S
29·461	29·336	52·3	44·0	WN
28·966	28·981	49·0	44·8	W
29·445	29·572	49·2	41·4	WNW

NOVEMBER, 1898.

KEW.								GLASGOW.							
	BAROMETER.				TEMPERATURE.		Direction of wind at noon		BAROMETER.				TEMPERATURE.		Direction of wind at noon
Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max	Min.		Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max	Min.	
1	29·880	29·988	29·991	30·037	53·1	33·1	W	1	29·627	29·658	29·602	29·455	50·3	42·0	SW
2	29·952	29·868	29·751	29·700	57·3	43·1	SSW	2	29·196	29·061	29·072	29·157	56·1	49·1	WSW
3	29·630	29·659	29·703	29·820	60·0	45·6	W	3	29·209	29·281	29·300	29·326	50·9	40·1	WSW
4	29·896	29·930	29·862	29·860	54·2	40·0	SW	4	29·390	29·418	29·408	29·398	48·6	41·5	WSW
5	29·788	29·776	29·782	29·908	56·1	43·1	SW	5	29·422	29·480	29·552	29·699	49·8	43·1	WSW
6	30·020	30·126	30·104	30·121	54·1	36·0	SW	6	29·793	29·862	29·845	29·834	50·8	41·9	SSW
7	30·070	30·046	29·935	29·915	52·1	43·0	SSE	7	29·793	29·799	29·741	29·739	52·3	47·7	SSW
8	29·919	29·997	30·014	30·099	55·3	43·2	SSE	8	29·735	29·870	29·969	30·086	51·2	43·6	NE
9	30·117	30·182	30·122	30·113	56·2	49·2	ENE	9	30·127	30·171	30·135	30·130	47·4	40·1	WSW
10	30·073	30·062	29·996	30·027	54·8	42·8	E	10	30·065	30·060	30·000	30·017	43·5	37·1	NNE
11	30·018	30·028	29·965	29·941	51·1	42·9	E	11	29·995	29·981	29·905	29·831	41·1	34·9	NE
12	29·845	29·746	29·664	29·612	53·6	45·4	E	12	29·702	29·617	29·505	29·537	51·2	40·3	SSE
13	29·674	29·872	30·007	30·134	54·5	36·8	SW	13	29·735	29·939	30·012	30·027	50·1	38·3	S
14	30·213	30·294	30·276	30·317	49·2	33·9	WSW	14	29·977	30·000	30·020	30·103	47·2	37·9	SW
15	30·306	30·302	30·257	30·237	51·9	40·1	WSW	15	30·137	30·163	30·124	30·105	48·2	40·4	WNW
16	30·198	30·228	30·216	30·251	56·1	49·9	WSW	16	30·035	30·036	30·036	30·032	54·3	42·4	NE
17	30·239	30·286	30·272	30·319	54·1	50·0	W	17	30·042	30 127	30·188	30·241	55·1	51·6	WSW
18	30·312	30·331	30·294	30·289	52·1	45 4	NE	18	30·237	30·255	30·240	30·258	53·1	48·3	SSW
19	30·225	30·209	30·163	30·155	48·3	41·8	E	19	30·256	30·270	30·182	30·158	48·4	40·3	W
20	30·123	30·153	30·123	30·133	49·3	43·0	S	20	30·067	29·993	29·934	29·962	43·7	36·0	W
21	30·090	30·053	29·966	29·958	47·2	39·6	NNE	21	29·994	30·039	30·070	30·220	43·7	34·9	W
22	29·985	30·056	30·034	29·922	39·8	28·4	N	22	30·224	30·175	29·965	29·649	35·4	26·9	WNW
23	29·644	29·357	29·130	29·055	41·2	29·1	S	23	29·302	29·173	29·072	29·070	37·1	28·9	E
24	28·947	28·946	28·862	28·795	46·0	37·8	E	24	29·070	29·100	29·031	28·965	38·7	33·3	E
25	28·732	28·795	28·857	28·943	50·8	43·3	S	25	28·898	28·919	28·935	29·046	45·1	37·9	ENE
26	28·936	28·980	29·001	29·046	45·9	43·1	S	26	29·043	29·210	29·188	29·176	43·9	39·9	NE
27	29·059	29·149	29·197	29·306	45·6	36·0	WSW	27	29·114	29·197	29·307	29·430	42·0	36·0	N
28	29·336	29·343	29·314	29·406	41·6	34·7	N	28	29·481	29·576	29·595	29·637	37·4	29·6	N
29	29·465	29·577	29·611	29·713	40·7	31·7	NNW	29	29·593	29·555	29·484	29·516	34·9	24·5	N
30	29·753	29·841	29·820	29·837	45·2	29·3	WSW	30	29·559	29·484	29·360	29·381	49·7	33·1	SW

DECEMBER, 1898.

1	29·863	29·940	29·908	29·873	52·0	45·2	W	1	29·432	29·444	29·391	29·239	52·1	44·5	WSW
2	29·783	29·719	29·605	29 746	54·9	50·0	SW	2	29·191	29·061	29·084	29·441	51·9	38·9	W
3	29·834	29·889	29·909	29·894	54·0	48·0	SW	3	29·525	29·575	29·395	29·333	51·2	39·0	SSW
4	29·867	29·965	29·976	30·014	56·3	52·4	SW	4	29·352	29·425	29·411	29·448	53·4	47·4	SSW
5	30·016	30·040	30·036	30·065	55·0	53·1	SSW	5	29·407	29·477	29·513	29·592	56·1	50·8	SSW
6	30·029	30·017	29·922	29·951	55·9	49·9	SW	6	29·594	29·524	29·452	29·5 3	52·8	42·6	SW
7	29·820	29 696	29·697	29·832	50·3	40·7	SW	7	29·442	29·409	29·355	29·580	44·5	40·9	WSW
8	29·912	30·066	30·084	30·020	46·9	39·3	WNW	8	29·802	29·935	29·875	29·530	41·4	33·2	SE
9	29·739	29·693	29 858	30·084	51·5	42·1	W	9	29·290	29·343	29·520	29·674	47·1	40·0	W
10	30·145	30·169	30·278	30·403	54·2	43·4	W	10	29·467	29·722	29·930	30·011	52·1	43·6	W
11	30·430	30·495	30·471	30·482	54·7	50·6	WSW	11	30·026	30·109	30·118	30·084	54·2	46·6	SW
12	30·385	30·292	30·196	30·241	54·2	50·2	SW	12	29·925	29·760	29·956	30·166	53·1	42·6	SW
13	30·301	30·369	30·372	30·406	50·1	36·4	N	13	30·240	30·262	30·238	30·126	46·1	39·9	W
14	30·353	30·227	30·066	30·015	51·9	35·8	SW	14	29·920	29·838	29·808	29·841	51·1	41·9	W
15	30·055	30·166	30·225	30·271	49·3	38·7	NW	15	29·913	30·061	30·139	30·125	45·0	40·8	WNW
16	30·291	30·268	30·193	30·231	52·0	36·0	SW	16	30·003	29·947	29·983	30·062	52·1	41·8	W
17	30·239	30·275	30·235	30·221	52·1	49·3	SW	17	30·065	30·071	29·996	29·803	47·3	43·6	WSW
18	30·181	30·169	30·132	30 099	55·1	51·5	WSW	18	29·685	29·842	29·926	29·923	50·7	35·4	WNW
19	30·021	30·122	30·128	30·223	53·2	38·3	NW	19	29·847	29·847	30·039	30·207	41·1	34·4	WNW
20	30·305	30·400	30 402	30·415	40·2	33·0	NNW	20	30·287	30·352	30·231	30·278	45·7	33·9	W
21	30·345	30·414	30·431	30·468	42·4	31·6	NE	21	30·311	30·350	30·325	30·309	45·6	39·8	W
22	30·458	30·502	30·462	30·471	42·3	29·2	NE	22	30·265	30·218	30·149	30·113	46·8	42·4	SSW
23	30·439	30·439	30·369	30·357	41·1	27·3	S	23	30·047	30·013	29·944	29·948	47·7	43·7	SSW
24	30·350	30·378	30·389	30·429	41·6	28·6	S	24	29·935	29·994	30·076	30·085	48·6	44·1	W
25	30·379	30·373	30·297	30·268	47·6	39·7	SW	25	30·019	29·887	29·777	29·709	52·8	45·3	SW
26	30·175	30·125	30·027	29·923	51·2	43·0	SW	26	29·495	29·583	29·603	29·478	52·8	43·6	WSW
27	29·712	29·555	29·474	29·458	54·1	44·2	SSW	27	29·137	28·830	28·583	28·695	50·4	41·6	SW
28	29·458	29·554	29·638	29·725	44·6	35·9	SW	28	28·870	29·191	29·321	29·323	46·5	35·1	W
29	29·569	29·221	29·050	29·120	50·0	37·0	SSW	29	29·226	29·123	29·188	29·422	39·4	35·8	E
30	29·367	29·716	29·887	29·966	42·9	28·2	NNW	30	29·606	29·747	29·790	29·755	38·5	30·5	WNW
31	29·888	29·688	29·394	29·317	44·1	26·9	S	31	29·520	29·240	29·186	29·189	41·4	30·1	ESE

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Transactions 1898-99.

Vol. XVII, Plate XXXIII.

A TEMPERATURES AND THE DIRECTION
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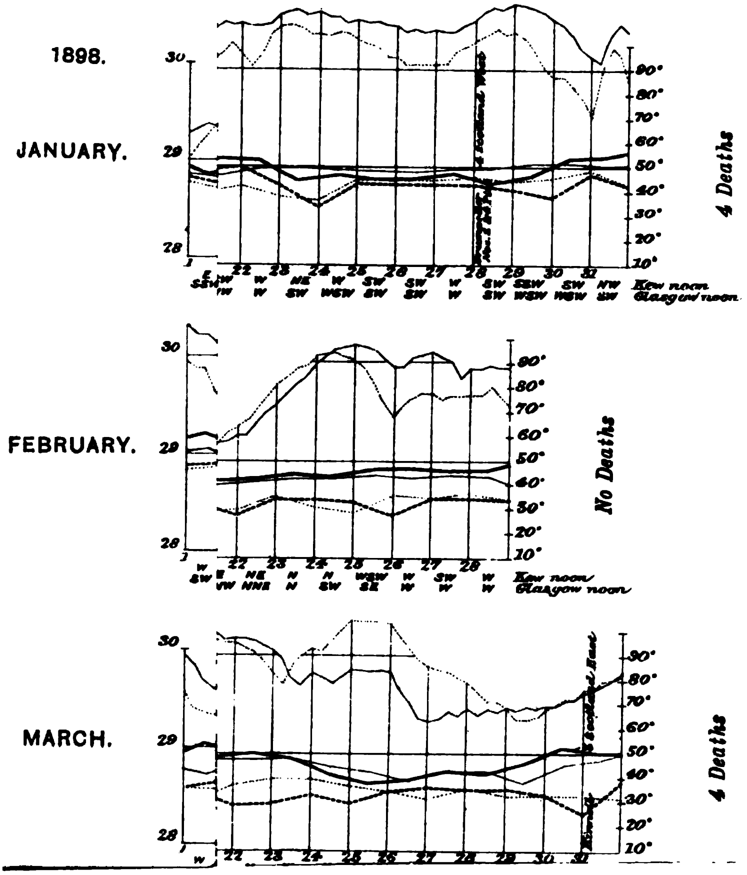
D.



NOVEMBER, 1898.

KEW.								GLASGOW.							
	BAROMETER.				TEMPERATURE.		Direction of wind at noon		BAROMETER.				TEMPERATURE.		Direction of wind at noon
Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max	Min.		Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max	Min.	
1	29·880	29·988	29·991	30·037	53·1	33·1	W	1	29·627	29·658	29·602	29·455	50·3	42·0	SW
2	29·952	29·868	29·751	29·700	57·3	43·1	SSW	2	29·196	29·061	29·072	29·157	56·1	49·1	WSW
3	29·630	29·659	29·703	29·820	60·0	45·6	W	3	29·209	29·281	29·300	29·326	50·9	40·1	WSW
4	29·896	29·930	29·862	29·860	54·2	40·0	SW	4	29·390	29·418	29·408	29·398	48·6	41·5	WSW
5	29·788	29·776	29·782	29·908	56·1	43·1	SW	5	29·422	29·480	29·552	29·699	49·8	43·1	WSW
6	30·020	30·126	30·104	30·121	54·1	36·0	SW	6	29·793	29·862	29·845	29·834	50·8	41·9	SSW
7	30·070	30·046	29·935	29·915	52·1	43·0	SSE	7	29·793	29·799	29·741	29·739	53·3	47·7	SSW
8	29·919	29·997	30·014	30·099	55·3	43·2	SSE	8	29·735	29·870	29·969	30·066	51·2	43·6	NE
9	30·117	30·182	30·122	30·113	56·2	49·2	ENE	9	30·127	30·171	30·135	30·130	47·4	40·1	WSW
10	30·073	30·062	29·996	30·027	54·8	42·8	E	10	30·065	30·060	30·000	30·017	43·5	37·1	NNE
11	30·018	30·028	29·965	29·941	51·1	42·9	E	11	29·995	29·981	29·905	29·831	41·1	34·9	NE
12	29·845	29·746	29·664	29·612	53·6	45·4	E	12	29·702	29·617	29·505	29·537	51·2	40·3	SSE
13	29·674	29·872	30·007	30·134	54·5	36·8	SW	13	29·735	29·939	30·012	30·027	50·1	38·3	S
14	30·213	30·294	30·276	30·317	49·2	33·9	WSW	14	29·977	30·000	30·020	30·103	47·2	37·9	SW
15	30·306	30·302	30·257	30·237	51·9	40·1	WSW	15	30·137	30·163	30·124	30·105	48·2	40·4	WNW
16	30·198	30·228	30·216	30·251	56·1	49·9	WSW	16	30·035	30·036	30·036	30·032	54·3	42·4	NE
17	30·239	30·286	30·272	30·319	54·1	50·0	W	17	30·042	30·127	30·188	30·241	55·1	51·6	WSW
18	30·312	30·331	30·294	30·289	52·1	45·4	NE	18	30·237	30·255	30·240	30·258	53·1	48·3	SSW
19	30·225	30·209	30·163	30·155	48·3	41·8	E	19	30·256	30·270	30·182	30·158	48·4	40·2	W
20	30·123	30·153	30·123	30·133	49·3	43·0	S	20	30·067	29·993	29·934	29·962	43·7	36·0	W
21	30·090	30·053	29·966	29·958	47·2	39·6	NNE	21	29·994	30·039	30·070	30·220	43·7	34·9	W
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23	29·644	29·357	29·130	29·055	41·3	29·1	S	23	29·302	29·173	29·072	29·070	37·1	28·9	E
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25	28·732	28·795	28·857	28·943	50·8	43·3	S	25	28·898	28·919	28·935	29·046	45·1	37·9	ENE
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28	29·336	29·343	29·314	29·406	41·6	34·7	N	28	29·481	29·576	29·595	29·637	37·4	29·6	N
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1	29·863	29·940	29·908	29·873	52·0	45·2	W	1	29·432	29·444	29·391	29·239	52·1	44·5	WSW
2	29·783	29·719	29·605	29·746	54·9	50·0	SW	2	29·191	29·064	29·084	29·441	51·9	38·9	W
3	29·834	29·889	29·909	29·894	54·0	48·0	SW	3	29·525	29·575	29·395	29·333	51·2	39·0	SSW
4	29·867	29·965	29·976	30·014	56·3	52·4	SW	4	29·352	29·425	29·411	29·448	53·4	47·4	SSW
5	30·016	30·040	30·036	30·065	55·0	53·1	SSW	5	29·407	29·477	29·513	29·592	56·1	50·8	SSW
6	30·029	30·017	29·922	29·951	55·9	49·9	SW	6	29·594	29·524	29·452	29·5 3	52·8	42·6	SW
7	29·820	29·696	29·697	29·832	50·3	40·7	SW	7	29·442	29·409	29·355	29·580	44·5	40·9	WSW
8	29·912	30·066	30·084	30·020	46·9	39·3	WNW	8	29·802	29·935	29·875	29·530	41·4	33·2	SE
9	29·739	29·693	29·858	30·084	51·5	42·1	W	9	29·290	29·343	29·520	29·674	47·1	40·0	W
10	30·145	30·169	30·278	30·403	54·2	43·4	W	10	29·467	29·722	29·930	30·011	52·1	43·6	W
11	30·430	30·495	30·471	30·482	54·7	50·6	WSW	11	30·026	30·109	30·118	30·084	54·2	46·6	SW
12	30·385	30·292	30·196	30·241	54·2	50·2	SW	12	29·925	29·760	29·956	30·166	53·1	42·6	SW
13	30·301	30·369	30·372	30·406	50·1	36·4	N	13	30·240	30·262	30·238	30·126	46·1	39·9	W
14	30·353	30·227	30·066	30·015	51·9	35·8	SW	14	29·920	29·838	29·808	29·841	51·1	41·9	W
15	30·055	30·166	30·225	30·271	49·3	38·7	NW	15	29·913	30·061	30·139	30·125	45·0	40·8	WNW
16	30·291	30·268	30·193	30·231	52·0	36·0	SW	16	30·003	29·947	29·983	30·062	52·1	41·8	W
17	30·239	30·275	30·235	30·221	52·1	49·3	SW	17	30·065	30·071	29·996	29·803	47·3	43·6	WSW
18	30·181	30·169	30·132	30·099	55·1	51·5	WSW	18	29·685	29·842	29·926	29·923	50·7	35·4	WNW
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22	30·458	30·502	30·462	30·471	42·3	29·2	NE	22	30·265	30·218	30·149	30·113	46·8	42·4	SSW
23	30·439	30·439	30·369	30·357	41·1	27·3	S	23	30·047	30·013	29·944	29·948	47·7	43·7	SSW
24	30·350	30·378	30·389	30·429	41·6	28·6	S	24	29·935	29·994	30·076	30·085	48·6	44·1	W
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27	29·712	29·555	29·474	29·458	54·1	44·2	SSW	27	29·137	28·830	28·583	28·695	50·4	41·6	SW
28	29·458	29·554	29·638	29·725	44·6	35·9	SW	28	28·870	29·191	29·321	29·333	46·5	36·1	W
29	29·569	29·221	29·050	29·120	50·0	37·0	SSW	29	29·226	29·123	29·188	29·422	39·4	35·8	E
30	29·367	29·716	29·887	29·966	42·9	28·2	NNW	30	29·606	29·747	29·790	29·755	38·5	30·5	WNW
31	29·888	29·688	29·394	29·317	44·1	26·9	S	31	29·520	29·240	29·186	29·189	41·4	30·1	ESE

A TEMPERATURES AND THE DIRECTION THER WITH THE EXPLOSIONS D.

1898.

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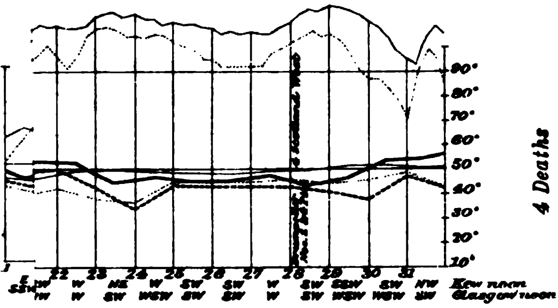

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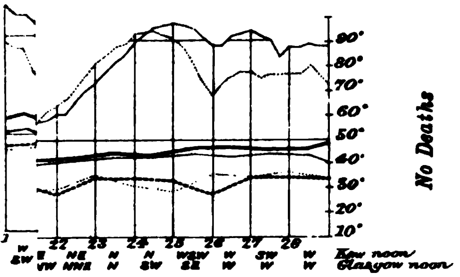

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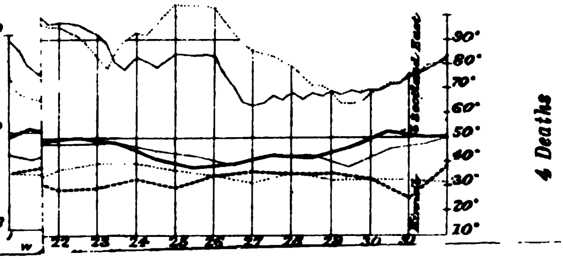

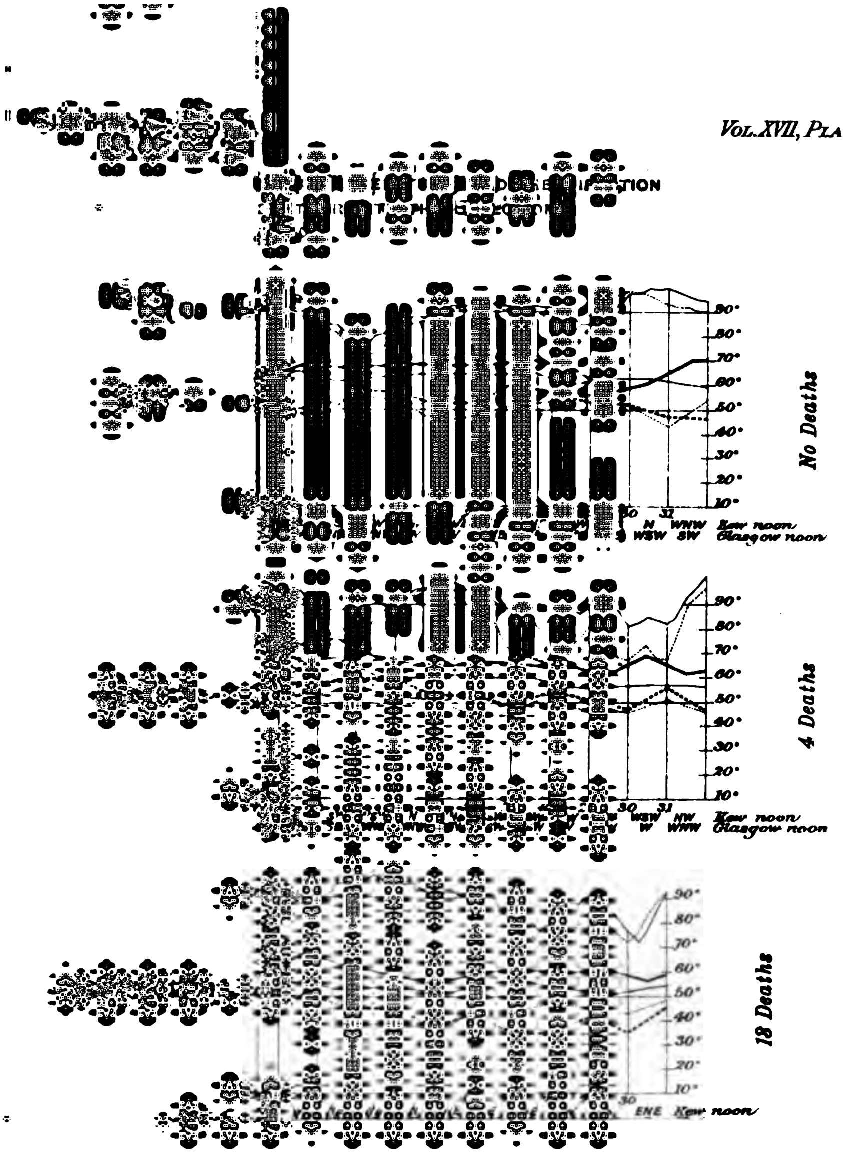
No Deaths
90°
80°
70°
60°
50°
40°
30°
20°
10°
30
31
N
WNW
Kew noon
WSW
SW
Glasgow noon
4 Deaths
90°
80°
70°
60°
50°
40°
30°
20°
10°
30
31
WSW
NW
Kew noon
W
WNW
Glasgow noon
18 Deaths
90°
80°
70°
60°
50°
40°
30°
20°
10°
30
ENE
Kew noon

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EXPLANATIONS.

The — at the beginning of a line denotes the repetition of a word; and in the case of Names, it includes both the Christian Name and the Surname.

Discussions are printed in *italics*.

The following contractions are used:—

C.—Chesterfield and Midland Counties Institution of Engineers.
M.—Midland Institute of Mining, Civil and Mechanical Engineers.
S.—Mining Institute of Scotland.
N.E.—North of England Institute of Mining and Mechanical Engineers.
N.S.—North Staffordshire Institute of Mining and Mechanical Engineers.
S.S.—South Staffordshire and East Worcestershire Institute of Mining Engineers.

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